DOUBLE NUMBER

VOL. XXXVI SEPTEMBER, 1920 Nos. 1 & 2

JOURNAL

OF THE

Elisha Mitchell Scientific Society

CONTENTS

PROCEEDINGS OF THE ELISHA MITCHELL SCIENTIFIC SOCIETY, DECEMBER, 1916, TO MARCH, 1920 1

PROCEEDINGS OF THE N. C. ACADEMY OF SCIENCE 7

THE THEORY OF RELATIVITY. *Andrew H. Patterson* 19

A NEW METHOD FOR LAYING OUT CIRCULAR CURVES BY DEFLECTIONS FROM THE P. I. *T. F. Hickerson* 42

A REMARKABLE FORM OF SKELETAL ELEMENT IN THE LITHISTID SPONGES (A CASE OF ANALOGICAL RESEMBLANCE). *H. V. Wilson* 54

THE TURTLES OF NORTH CAROLINA. *C. S. Brimley* 62

A LITTLE KNOWN VETCH DISEASE. *Frederick A. Wolf* 72

NOTES ON THE MOSQUITO FAUNA OF NORTH CAROLINA. *Franklin Sherman* 86

AN INTERESTING FERTILIZER PROBLEM. *H. B. Arbuckle* 94

AZALEA ATLANTICA ASHE AND ITS VARIETY LUTEO-ALBA N. VAR. *W. C. Coker* 97

A NEW SPECIES OF ACHLYA. *W. C. Coker* and *J. N. Couch* 100

ISSUED QUARTERLY

CHAPEL HILL, N. C., U. S. A.

ENTERED AT THE POSTOFFICE AS SECOND-CLASS MATTER

The Elisha Mitchell Scientific Society

W. C. COKER, President.

J. M. BELL, Vice-President.

A. W. HOBBS,
Secretary and Treasurer.

F. P. VENABLE,
Permanent Secretary.

EDITORS OF THE JOURNAL:

W. C. COKER.

COLLIER COBB.

J. M. BELL.

JOURNAL OF THE ELISHA MITCHELL SCIENTIFIC SOCIETY—Quarterly. Price $2.00 per year; single numbers, 50 cents. Most numbers of former volumes can be supplied. Direct all correspondence to the Permanent Secretary, at the University of North Carolina, Chapel Hill, N. C.

In addition to original papers on scientific subjects this Journal publishes the Proceedings of the Elisha Mitchell Scientific Society, and the Proceedings of the North Carolina Academy of Science, as well as abstracts of papers on scientific subjects published elsewhere by members of the Faculty of the University of North Carolina.

Published for the Society
by the
University of North Carolina

PLATE 1

AZALEA ATLANTICA. (left)
AZALEA ATLANTICA VAR. LUTEO-ALBA. (right)
½ Natural Size

JOURNAL

OF THE

Elisha Mitchell Scientific Society

Volume XXXVI SEPTEMBER, 1920 Nos. 1 and 2

PROCEEDINGS OF THE ELISHA MITCHELL SCIENTIFIC SOCIETY, DECEMBER, 1916, TO MARCH, 1920.

225TH MEETING—DECEMBER 12, 1916

A. H. PATTERSON—*Shrapnel in the Making.*

J. M. BELL—*Some Recent Work in Crystal Structure.*

226TH MEETING—FEBRUARY 20, 1917

H. H. WILLIAMS—*The Logic of Science.*

COLLIER COBB—*Recent Changes in Currituck Sound* (Illustrated).

227TH MEETING—MARCH 13, 1917

H. R. TOTTEN—*Growing Mushrooms in Pure Culture.*

J. S. HOLMES—*Some Notes on the Occurrence of Landslides.*

BUSINESS MEETING—SEPTEMBER 26, 1917

ELECTION OF OFFICERS:

President—J. G. Beard.
Vice-President—J. M. Bell.
Permanent Secretary—F. P. Venable.
Recording Secretary—W. W. Rankin, Jr.
Editorial Committee—W. C. Coker, chairman; Collier Cobb, M. H. Stacy.

228TH MEETING—OCTOBER 9, 1917

P. H. DAGGETT—*Modern Tendencies in Engineering Education.*

F. P. VENABLE—*The Luminosity of Insects—A Chemical Phenomenon.*

229TH MEETING—NOVEMBER 13, 1917

COLLIER COBB—*Cave Dwellings and their Relation to Geology.*

230TH MEETING—DECEMBER 11, 1917.

W. DEB. MACNIDER—*The Stability of the Acid-Base Equilibrium of the Blood in Animals of Different Ages.*

ARCHIBALD HENDERSON—*The Role of Pascal's Theorem in Modern Geometry.*

231ST MEETING—FEBRUARY 26, 1918

H. V. WILSON—*Contributions of French Scientists as Brought out at the San Francisco Exposition.*

H. W. CHASE—*Some Modern Tendencies in Psychological Thought.*

232D MEETING—MARCH 12, 1918

W. C. COKER—*Corn (Illustrated).*

A. S. WHEELER—*The Production of Toluol.*

233D MEETING—APRIL 9, 1918

J. W. LASLEY—*Some Everyday Problems.*

F. P. VENABLE—*Luminescence and Radioactivity of the Zircons.*

P. H. DAGGETT—*Demonstration of a New Telephone Signaling System.*

BUSINESS MEETING—OCTOBER, 1918

The old officers were re-elected for the year 1918-19, during which period the regular meetings were suspended.

234TH MEETING—APRIL 15, 1919

ARCHIBALD HENDERSON—*Some Points in Gunnery for Heavy Artillery.*

F. P. VENABLE—*The North Carolina Academy of Science.*

235TH MEETING—MAY 13, 1919

W. DEB. MACNIDER—*Influence of the Age of an Organism on Regeneration.*

A. S. WHEELER—*New Napthalene Dyes.*

J. M. BELL—*Investigations on the Nitrotoluenes.*

ELECTION OF OFFICERS:

President—*W. C. Coker.*
Vice-President—J. M. Bell.
Permanent Secretary—F. P. Venable.
Recording Secretary—A. W. Hobbs.
Editorial Committee—W. C. Coker, chairman; J. M. Bell, Collier Cobb.

236TH MEETING—NOVEMBER 11, 1919.

H. V. WILSON—*Some Crustacea of the North Carolina Coast.*

F. P. VENABLE and D. H. JACKSON—*Reactions of Hydrochloric and Hydrobromic Acids with Potassium Permanganate.*

237TH MEETING—DECEMBER 9, 1919

J. N. COUCH—*A New Species of Water Mold with Observations on Fertilization.*

T. F. HICKERSON—*A New Method For Laying Out Curves in Road Location.*

238TH MEETING—JANUARY 13, 1920.

J. J. WOLFE—*The Plankton of Chesapeake Bay.*

The speaker presented in brief form the results obtained in a plankton survey of these waters, made by the speaker in collaboration with Prof. Bert Cunningham, the object of which was to throw some light on the kind and abundance of organisms that may serve as fish food. The collections on which the work was based were made by the U. S. Bureau of Fisheries.

The details of collection and the methods employed in the study were explained at some length. Charts and tables compiled from the data gathered were presented and the conclusions drawn which may be summarized as follows:

1. The volume of matter suspended in the water bears little or no relation to the number of organisms present.

2. There is a gradual increase in volume with increasing depth due in part to detritus and in part to an increase in organisms.

3. There is a great variation in number of organisms in different parts of the Bay on the same day and at the same depths, the cause of which is not determined. Locations and temperature are ruled out as causes. The data, too meagre as yet, point to the tides as a possible explanation.

4. There are two crests during the year, April-May and September-October, due to a tremendous increase of individuals belonging to only one or two species rather than as might be expected to a general increase in all species represented.

5. There seems to be a definite relation between temperature and number of organisms, the optimum lying between 46° and 55° F.

6. There is a noteworthy absence of *Copepods* certainly due to some error in the method of collection.

7. Neither "count" nor "volume" gives an absolutely true indication of food available. These two in connection with "incineration" would probably give a more correct idea.

239TH MEETING—FEBRUARY 10, 1920

F. P. VENABLE—*The Chemistry of Zirconium.*

This paper will be published in full in this Journal in a later number.

W. F. PROUTY—*Notes on the Geology of a Portion of Clay County, Alabama.*

The fundamental or metamorphic rocks of Clay County, Alabama, have been generally considered of Precambrian age. There is nothing published concerning the age of the associated intrusives. Dr. Smith, of the University of Alabama, has demonstrated the Carboniferous age of a small area in the phyllites of western Clay County. The speaker has recently widely extended, in the phyllite belt, the area of known Carboniferous rocks and has demonstrated the post Carboniferous age of the belt of green schists which everywhere separate the phyllites on the west from the mica schists on the east.

The workable flake graphite ores or the mica schist belt are shown to be of epigenetic origin and the association of the ores with the more quartzitic and coarse-grained, originally sedimentary beds, leads to the conclusion that the graphitic ores resulted from the metamorphism of petroliferous strata.

240TH MEETING—MARCH 9, 1920

J. F. DASHIELL—*Double Habit Formation by Animals, Children, and Adults.*

The problem approached was that as to the relative efficiency of learning two habits by practicing them alternately (the Alternate

Method) or by getting one to some extent fixed before practicing the other (the Complete Method). Data were obtained by the study of the learning of mazes by rats, of mazes by children, and of mazes by adults; then the scope was extended to include the formation of another pair of perceptual-motor habits, card sorting, and further still to include a pair of habits involving very little of the motor element, addition.

The particular technique of the different experiments was intentionally varied considerably: (a) in temporal distribution of trials; (b) in stage at which shift was made from one to the other habit by the Complete Method; (c) in arrangement of controls—division of subject into groups; (d) in methods of scoring; (e) in incentives used, (f) in subjects' previous familiarity with the habits to be learned; (g) in their knowledge of the number and order of the habits to be learned; (h) in their knowledge of the nature of the problem investigated. Thus, the general results found may be considered as independent of particular details of technique and to be of general bearing.

For results, it was found that in all the forms of double habit formation studied, learning by the Complete Method was more economical than learning by the Alternate Method. This was indicated in the different sets of experiments in terms of the different criteria of efficiency respectively applicable. They included: (a) number of trials necessary to fix a habit; (b) degree of regularity in improvement; (c) average amounts of scores on individual trials; (d) rate of acceleration of improvement.

The complete paper will appear in an early number of *The Psychological Review.*

J. B. BULLITT—*Report on Autopsies on 25 Cases of Influenza Pneumonia.*

Extensive cutaneous emphysema was encountered in one case. Firm, fibrous pleural adhesions existed in six cases, in four of which the lungs showed old scars of apparently healed tuberculosis while one showed fibrinous exudate on the pleura, four of these exudates being thick and shaggy. In three of these there was serous effusion; in two, purulent effusion. All cases exhibited the lobular type of pneumonia. In seven there was also distinct lobar consolidation, the lobular process in these being but slightly evident. Numerous bronchiectatic abscesses occurred in four cases, while in four others (three of them associated with labor consolidation) there was massive

necrosis involving the whole or the greater part of a lobe. Meningitis existed in five cases—two due to the meningococcus, one to the meningococcus and pneumococcus together, while in two the organism was not discovered. In all cases of more than one week duration more or less extensive organization has occurred. Two men who lived about five weeks died suddenly during apparent convalescence. The lungs showed little evidence of active inflammation, but organization has obliterated the greater part of the pulmonary tissue. These seem analogous to those cases of nephritis in which the repair process strangles the glomeruli and kills a patient who may have survived the original toxemia.

PROCEEDINGS OF THE NINETEENTH MEETING OF THE NORTH CAROLINA ACADEMY OF SCIENCE, HELD AT STATE COLLEGE, WEST RALEIGH, N. C., APRIL 30-MAY 1, 1920.

The executive committee met in the offices of Prof. Z. P. Metcalf April 30, at 12:00 M., with the following members present: President A. H. Patterson, Secretary R. W. Leiby and member Z. P. Metcalf. The secretary made a preliminary report on finances, membership, etc., following which the policies of the Academy and other questions were discussed. A total of 28 new members were elected as follows:

Josiah S. Babb, Asst. in Geology, U. N. C., Chapel Hill.

Dr. H. P. Barret, Physician, Charlotte.

Wm. Hande Browne, Prof. Elec. Engr., State College, West Raleigh.

Dr. J. B. Bullitt, Prof. Path., U. N. C., Chapel Hill.

J. N. Couch, Asst. in Botany, U. N. C., Chapel Hill.

Dr. J. B. Derieux, Dept. Physics, State College, W. Raleigh.

A. A. Dixon, Dept. Physics, State College, W. Raleigh.

Paul Gross, Ph. D., Chemist, Trinity College, Durham.

Miss Pattie J. Groves, Instr. Science, Durham High School, Durham.

V. R. Haber, Asst. Investigations, Ent., State Dept. Agr., Raleigh.

Dr. J. O. Halverson, Expert Animal Nutrition, State Dept. Agr., Raleigh.

C. M. Heck, Dept. Physics, State College, W. Raleigh.

Miss Alma Holland, Asst. in Botany, U. N. C., Chapel Hill.

J. E. Ivey, Poultry Path., State College, W. Raleigh.

S. G. Lehman, Asst. Plant Path., State College, W. Raleigh.

A. L. Lugn, Prof. Physics and Chemistry, Lenoir College, Hickory.

Dr. Wm. F. Prouty, Stratigraphic Geol., U. N. C., Chapel Hill.

R. F. Revson, Chemist, 210 S. Tryon St., Charlotte.

G. H. Satterfield, Trinity College, Durham.

Prof. M. E. Sherwin, Prof. Soils, State College, W. Raleigh.

I. V. Shunk, Asst. Prof. Botany, State College, W. Raleigh.

M. R. Smith, Extension Ent., State Dept. Agr., Raleigh.

Ira W. Smithey, U. N. C., Chapel Hill.

HAYWOOD M. TAYLOR, U. N. C., Chapel Hill.
DR. WALTER F. TAYLOR, Asso. Prof. Bacter. and Hygiene, W. F. C., Wake Forest.
DR. B. W. WELLS, Prof. Botany, State College, W. Raleigh.
C. B. WILLIAMS, Dean, State College, W. Raleigh.
J. H. WILLIAMS, Instr. Zool. & Ent., State College, W. Raleigh.

The executive committee then adjourned.

At 2:15 P. M. the first session of the annual meeting was called to order by Pres. A. H. Patterson, who made some remarks chiefly concerning the time allowance for presentation of papers. The following committees were then appointed: Auditing—C. S. Brimley, T. F. Hickerson, F. A. Wolf; Nominations—J. J. Wolfe, W. C. Coker, W. A. Withers; Resolutions—C. W. Edwards, H. B. Arbuckle, Miss Mary Petty.

Papers were then called for, the reading and discussion of which was carried on until 5:00 P.M. when the session was adjourned.

The Academy reconvened at 8:15 P. M. to listen to the Presidential address by A. H. Patterson on "The Einstein Theory of Relativity." Previous to the presidential address, the Academy was formally welcomed by Dr. W. C. Riddick, President of the College, the response being made by Professor Patterson.

The Academy was again called to order on Saturday morning at nine o'clock for a business session. The Secretary read the minutes of the previous meeting, which were approved. The Treasurer's report was read and referred to the Auditing Committee. The matter of increasing dues was discussed. Professor Metcalf presented the proposition of the Academy affiliating with the American Association for the Advancement of Science. This was freely discussed and referred by motion to the Executive Committee with power to act. The question of securing State support for the Academy in the sum of $500.00 to $1,000.00 was discussed and motion was adopted to refer to Executive Committee to look into matter and if found practicable to authorize the President to appoint a committee to present the matter to the next Legislature. The committee on Science Instruction in the High Schools as related to the College, was continued with one change in personnel, the substitution of Mr. Bert Cunningham for Dr. J. J. Wolfe. Motion was then adopted, following pro and con discussion, that the Secretary be allowed ten per cent of all moneys collected by him for the Academy, effective next year.

Motion adopted that we accept the invitation of Wake Forest College to meet there next year.

The nominating committee then made its report as follows:

President—Z. P. Metcalf, W. Raleigh.

Vice-President—J. M. Bell, Chapel Hill.

Secretary-Treasurer—R. W. Leiby, Raleigh.

Additional members Executive Committee: H. R. Totten, R. N. Wilson, F. A. Wolfe.

Report was adopted and Secretary authorized to cast the ballot.

Motion was then adopted that the following telegram be sent past President and Secretary, E. W. Gudger:

"The North Carolina Academy of Science in annual session assembled, deeply appreciating the splendid constructive service which you rendered her through so many years, sends you greeting and begs that you accept her thanks for this most devoted service which we well know was a labor of love, and sincerely hopes that events may so shape themselves that you may at an early date again actively share in her work and achievement."

Following the business session the presentation of papers was continued before the joint session of the Academy and Chemists until 12:30.

At 1:30 the Academy reconvened for the further presentation of papers. During this session the report of the Auditing Committee was adopted which found the books correct and suggested the payment of the nominal sum of $5.00 to the Secretary's stenographer for clerical work. The report of the Resolutions Committee was then read and adopted as follows:

Resolved, That we, the members of the North Carolina Academy of Science, sorrow because of the demise of our member and fellow worker, Mrs. Fannie Carr Bivins, head of the Science Department of the Durham City Schools, and express our recognition of her unselfish and enthusiastic work as student and teacher which made her life such a notable contribution to the advancement of science in her community.

That we express our hearty appreciation of the kindness, courtesy, and co-operation of the President and Faculty of the N. C. State College of Agriculture and Engineering on the occasion of the nineteenth annual meeting of the Academy and especially of the generous and hospitable manner in which we have individually been entertained.

Following the completion of the program the Academy adjourned *sine die* at 3:15 P. M.

REPORT OF TREASURER, July 1, 1919-April 28, 1920

RECEIPTS		EXPENDITURES	
From former treasurer	$ 128.67	Rubber stamp	$ 1.00
Dues (back)	5.00	Postage and envelopes	13.72
Dues (current)	56.00	Stationery	5.25
Dues (advanced)	16.00	Multigraph letters (3)	3.00
Initiation fees	28.00	Printing programs	16.50
Savings acct. Int.	3.32	Incidentals	1.20
Total receipts	$ 236.99		$ 40.67
Total expenditures	40.67		
	$ 196.32		

Balance April 28, 1920 ..... $ 196.32
Balance May 31, 1920 (all bills paid) ..... $ 156.09

Following is present membership of the Academy. Those marked with asterisk were in attendance at meeting:

Andrews, W. H. ..... Chapel Hill
*Arbuckle, H. B. ..... Davidson
Babb, Josiah S. ..... Chapel Hill
Bahnson, F. F. ..... Winston-Salem
Balderston, Mark ..... Guilford College
Barret, H. P. ..... Charlotte
Beardslee, H. C. ..... Asheville
*Bell, J. M. ..... Chapel Hill
Binford, Raymond ..... Guilford College
Bonney, Miss F. C. ..... Hartsville, S. C.
Bottum, Miss F. R. ..... Raleigh
Brewer, C. E. ..... Raleigh
*Brimley, C. S. ..... Raleigh
Brimley, H. H. ..... Raleigh
*Browne, Wm. Hande ..... W. Raleigh
Bruner, S. C. ..... Santiago de las Vesgas, Cuba
Bullitt, J. B. ..... Chapel Hill
Bynum, J. C. ..... Chapel Hill
Cain, Wm. ..... Chapel Hill
Clapp, S. C. ..... Swannanoa
*Cobb, Collier ..... Chapel Hill
Cobb, Wm. B. ..... Columbia
*Coker, W. C. ..... Chapel Hill
Collett, R. W. ..... Willard
Coman, J. H. ..... Durham
*Couch, J. N. ..... Chapel Hill

Cunningham, Bert ..... Madison, Wis.
Davis, H. T. ..... Chapel Hill
*Derieux, J. B. ..... W. Raleigh
*Dixon, A. A. ..... W. Raleigh
Dixon, L. F. ..... Weaverville
Dobbins, C. N. ..... Chapel Hill
Downing, J. S. ..... Elsmere, Del.
*Edwards, C. W. ..... Durham
Edgerton, F. N., Jr. ..... Athens, Ga.
Farmer, C. M. ..... Troy, Ala.
*Gross, Paul ..... Durham, N. C.
*Groves, Miss Pattie J. ..... Durham
Gudger, E. W. ..... Greensboro
*Haber, V. R. ..... Raleigh
*Halverson, J. O. ..... Raleigh
Hatley, C. C. ..... Durham
*Heck, C. M. ..... West Raleigh
Henderson, Archibald ..... Chapel Hill
Hewlett, C. W. ..... Greensboro
*Hickerson, T. F. ..... Chapel Hill
Hobbs, A. W. ..... Chapel Hill
Hoffman, S. W. ..... Statesville
*Holland, Miss Alma ..... Chapel Hill
Holmes, J. S. ..... Chapel Hill
Ives, J. D. ..... Charleston, S. C.
*Ivey, J. E. ..... West Raleigh
Johnson, E. D. ..... Asheville
*Kilgore, B. W. ..... Raleigh
*Krausz, H. B. ..... Raleigh
Lake, J. L. ..... Wake Forest
Lanneau, J. F. ..... Wake Forest
*Lehman, S. G. ..... West Raleigh
*Leiby, R. W. ..... Raleigh
Lewis, R. H. ..... Raleigh
Lugn, A. L. ..... Hickory
Lyon, Miss Mary ..... Red Springs
*Marion, S. J. ..... Raleigh
Markham, Blackwell ..... Chapel Hill
Mendenhall, Miss Gertrude W. ..... Greensboro
*Metcalf, Z. P. ..... West Raleigh
Nowell, J. W. ..... Wake Forest
*Patterson, A. H. ..... Chapel Hill
*Pegram, W. H. ..... Durham
Petty, Miss Mary ..... Greensboro
*Pillsbury, J. P. ..... West Raleigh
*Plummer, J. K. ..... Raleigh
Poteat, W. L. ..... Wake Forest

Pratt, J. H. .....Chapel Hill
*Prouty, Wm. F. .....Chapel Hill
Randolph, E. O. .....College Station, Texas
Randolph, Mrs. E. O. .....College Station, Texas
Rankin, W. S. .....Raleigh
*Revson, R. F. .....Charlotte
*Rhodes, L. B. .....Raleigh
*Riddick, W. C. .....West Raleigh
*Robinson, Miss Mary .....Greensboro
*Satterfield, G. H. .....West Raleigh
*Saville, Thorndyke .....Chapel Hill
Seymore, Miss Mary F. .....Greensboro
Shaffer, Miss Blanch E. .....Greensboro
*Sherman, Franklin .....Raleigh
Sherrill, Miss Mary L. .....Greensboro
*Sherwin, M. E. .....West Raleigh
*Shore, C. A. .....Raleigh
*Shunk, I. V. .....West Raleigh
Smith, J. E. .....Ames, Iowa
*Smith, M. R. .....Tallulah, La.
Smithey, Ira W. .....Chapel Hill
*Spencer, Herbert .....West Raleigh
Stiles, C. W. .....Wilmington
Taylor, Haywood M. .....Chapel Hill
Taylor, Walter F. .....Wake Forest
*Totten, H. R. .....Chapel Hill
Vann, Miss Fannie E. .....Durham
Venable, F. P. .....Chapel Hill
*Wells, B. W. .....West Raleigh
*Wheeler, A. S. .....Chapel Hill
*Williams, C. B. .....West Raleigh
*Williams, J. H. .....West Raleigh
*Williams, L. F. .....West Raleigh
*Wilson, H. V. .....Chapel Hill
*Wilson, R. N. .....Durham
*Winters, R. Y. .....West Raleigh
*Withers, W. A. .....West Raleigh
*Wolf, F. A. .....West Raleigh
*Wolfe, J. J. .....Durham, N. C.

Total membership, 113.

The following papers were presented at the meeting:

The Einstein Theory of Relativity. A. H. PATTERSON. (Presidential address).

Appears in full in this issue.

A New Method for Laying out Circular Curves. T. F. HICKERSON.

Appears in full in this issue as a new method for laying out circular curves by deflections from the P. I.

A Remarkable Form of Skeletal Element in the Lithistid Sponges (A Case of Analogical Resemblance. H. V. WILSON.

Appears in full in this issue.

Animal Locomotion. H. H. BRIMLEY.

This paper treats of the means used in moving from place to place by the fishes, amphibians, reptiles, birds and mammals. The species in each class are artificially grouped according to their main locomotion characteristics.

Together with what may be called their normal methods of progression, the paper treats of fish that can walk and mammals that cannot; of mammals that can fly and birds without such powers; of reptiles that possess the power of volplaning through the air; of fish that travel while lying on the side; of mammals that use three or five members in their movements; of others that spend their lives upside down; of fish that possess the power of movement through the air; of birds that swim and dive while young and lose such powers on becoming adult; of mammals possessing exceptional locomotive powers both on land and in the water, and of birds that walk, fly, swim, dive and climb.

Single Spore Cultures of Coprinus radiatus. H. R. TOTTEN.

Reports the growth to maturity of *Coprinus radiatus* Fr. from a single spore. Mycelia from a spore germinated in broth of horse manure, and transferred to the following media, formed mature plants: Horse manure, cow manure, horse manure agar, corn meal agar, and peas. A review was given of Mlle. Bensaude's thesis on "Sexualité chez les Basidomycete," Paris, 1918, in which she proves that *Coprinus fimetarius* is a dioecious fungus. *Coprinus radiatus* was compared with *Coprinus fimetarius* and was shown to be monoecious. The hyphae of *Coprinus radiatus* also lacks the *clamped connections* so commonly seen on hyphae and always seen on the hyphae of *Coprinus fimetarius* before the formation of mature plants.

Genera of Lower Basidiomycetes not Before Reported from North America. W. C. COKER.

Reports the occurrence in Chapel Hill of three Genera; all growing on wood as saprophytes, and forming small pustules or expanded, resupinate layers. They are as follows:

Saccoblastia Möller. A remarkable genus with elongated basidia divided across into four cells as in the rusts; and arising in a peculiar way from the tip of a pendant pear-shaped sac. Three species have been reported, two from South Brazil and one from Poland. Our plant is considered a variety of *S. ovispora* Möller from South Brazil.

Platygloea Schroeter. Two species were found on Crepe Myrtle, both of which seem new. About nine others have been described from Europe and the tropics. Our plants seem nearest *Helicogloea Lagerheimi* Pat. which is usually considered as not generically distinct from Platygloea. Our species have small, crowded basidia borne in corymbs and two-celled by a cross partition.

Sirobasidium Möller. In this genus the basidia are borne in *chains* and are divided into two cells by an oblique wall or into four cells by longitudinal walls. Three species have been described, all from South America (one from Brazil, two from Equador). Our plant agrees well with the one from Brazil, *S. Brefeldianum* Möller.

Attention was also called to the Genus *Septobasidium*, which is well represented in America, but in which the basidia have been misunderstood.

The Turtles of North Carolina. C. S. BRIMLEY.

Appears in full in this issue.

The Life History of a Gall-Making Psyllid (Pachypsylla mamma Riley). Lantern. DR. B. W. WELLS.

Oviposition on under side of young hackberry leaf. Nymph migrates to upper side of leaf where galls are initiated near the principal veins. Nymph grows very slowly at first while gall on the other hand grows very rapidly. Usually but one insertion of the mouthparts into the leaf tissue is made, the insect keeping its position for an extended period. The nymph escapes from the gall in the fall, the adults appearing immediately afterward. These overwinter in bark crevices or ground debris.

Dreams and their Causes. C. S. BRIMLEY.

Paper gives concisely the author's opinion as to the causes of dreams, and illustrates the same by examples from his own personal experiences.

A Little-Known Vetch Disease. FREDERICK A. WOLF.

Appears in full in this issue.

Notes on the Mosquito Fauna of North Carolina. FRANKLIN SHERMAN.

Appears in full in this issue.

The Larger Corn Stalk-Borer (*Diatrae zeacolella* Dyar). Lantern. R. W. LEIBY.

Brief references to life-history as determined over a period of 5 years in North Carolina. Discussion of control measures which included late planting of corn and destruction of overwintering larvae by plowing out corn stubble in fall.

An Interesting Fertilizer Problem. H. B. ARBUCKLE.

Appears in full in this issue.

A Phenomenal Shoot. DR. B. W. WELLS.

A shoot found by Mrs. B. W. Wells near Raleigh, N. C., which measures 19 feet, 5 inches in length, was exhibited. It had grown from the stump of a beheaded tree of *Paulownia tomentosa* during the season of 1919. The base is 7.75 inches in circumference 2.50 inches diameter. The shoot possessed 20 internodes, the longest of which measures 19 inches.

A Peculiar Mycorhiza-forming Rhipzopogon on the Roots of Pine. H. R. TOTTEN.

Specimens of a species of Rhizopogon were shown on the roots of *Pinus Taeda* and *Pinus echinata.* This fungus attacks the young rootlets, forming a mycorhizal covering about each rootlet in a cluster. The fungal coats of several rootlets soon coalesce into a light creamy

mass of various forms and sizes. The fungus attacks the pine tissue, completely destroys the mass of enclosed rootlets, and remains lightly attached to the root. Many irregular cavities lined with basidia and spores are formed. The interior becomes a dark jelly mass, and the tougher coat later also breaks down.

Effect of Fertilizers on Germination and Seedling Growth of Corn and Cotton. M. E. SHERWIN.

This paper shows the effect of fertilizers on time required for germination and on rate of seedling growth of corn and cotton grown in galvanized pans 3½ inches each way. These results are in part in confirmation of field observations.

Heavy applications of soluble mineral fertilizers cause the greater delay in germination. Organic fertilizers cause the greater injury to the seedlings. Where germination seems to be poor as determined by the per cent of seeds which have "come up" the trouble will usually be found to be due to root injury where organic fertilizers are used and to inability of the seed to absorb sufficient water where mineral fertilizers are used.

To obviate the difficulty in germination and the root injury from organic fertilizers no fungicidal treatment has availed. Injury is less severe when the fertilizer is well mixed with the soil but to wholly obviate these troubles the fertilizer should be applied to the soil a week in advance of planting the seed. The injury appears to be much less in soil containing abundance of acid organic matter than in ordinary sand clay soils. The injury appears worse at high temperatures than at low temperatures.

The viability of the seed does not seem to have been impaired by contact with the soil solution containing sufficient nitrate of soda to prevent germination in two weeks' time.

Increasing the quantity of nitrate of soda has the same effect on rate of germination as decreasing the amount of soil moisture.

Borax, either alone or in trona-potash, is decidedly harmful to germination. Very small amounts of borax cause almost complete chlorosis of corn seedlings.

Some Investigations on the Compounds Isolated from the Polypores. JOSEPH T. MADDOX and RAYMOND BINFORD.

There has been little or no investigation done on the chemical analysis and isolation of the various compounds present and obtainable from any Polyporus. An investigation was made this past winter towards isolating under various conditions as many compounds as possible. Some eleven different compounds were obtained, which, owing to the lack of proper laboratory equipment, are as yet unidentified. This paper is only intended to give an account of the methods used and a study of the physical properties of each compound isolated.

New Ethers. A. S. WHEELER and S. C. SMITH.

A new group of ethers has been derived from chloral. The addition product obtained by the action of one mole of chloral upon one mole of m-nitroaniline is boiled with an alcohol. A molecule of water splits off and an ether of strong crystallizing power is obtained. These ethers are sensitive to acids but stable towards alkalies. The reaction with p-nitroaniline is best carried out by first making the chloral alcoholate and then treating this with the amine. The series of ethers under preparation include the three nitroanilines and methyl, ethyl, n-propyl, n-butyl and isoamyl alcohols.

p-Cymene, A New Solvent. A. S. WHEELER.

p-Cymene is now produced on a much larger scale than formerly since it is so easily obtained from spruce turpentine. It becomes, therefore, a useful solvent for high temperatures, its boiling point being 176.5°. It is a colorless hydrocarbon of the benzene series and is to be preferred where possible to such colored solvents as aniline and nitrobenzene and ill-smelling ones as pyridin. The solubility of a number of compounds of a wide range of types has been determined.

A Color Reaction for p-Cymene. A. S. WHEELER.

In p-cymene obtained from spruce turpentine are one or more impurities which give a color reaction with p-anisidine. The solid p-anisidine may be used or a solution in pure cymene. In samples where the cymene is still yellowish the coloration is very pronounced and is really not needed. The immediate coloration is pale yellow, deep yellow, brown or red depending on the degree of impurity.

Further in all cases the color deepens very noticeably in succeeding hours. If no coloration occurs in the diffused light of the laboratory within two hours the cymene is pure.

The following papers were read but no copies or abstracts furnished:

Some Biological Aspects of the Tidal Zone Region of the North Carolina Coast. Z. P. METCALF.

Recent Growth and Depletion of Sea-beaches on the North Carolina Coast. COLLIER COBB.

Electro-endosmosis of Clays. THORNDYKE SAVILLE.

Effect of Borax on Plant Growth and Notes on a Method for its Quantitative Determination in Fertilizers. OSCAR J. THEIS, JR., and H. B. ARBUCKLE.

Dyestuff Situation in the United States. R. F. REVSON.

Agricultural Geology (Read by title). JOHN E. SMITH.

The Wing Venation of the Heteroptera. HERBERT SPENCER.

Vitamines—A Review. W. A. WITHERS.

Further Studies on the Melting Points of the Nitrotoluenes. J. M. BELL.

A List of the Cicadellidae Taken at Swannanoa, North Carolina. Z. P. METCALF and HERBERT OSBORN.

The Conductivity of Nonaqueous Solutions. PAUL GROSS.

Behind the Barrier Beaches from Boston to Beaufort. COLLIER COBB.

Some New Types of Distillation Apparatus. PAUL GROSS.

R. W. LEIBY, *Secretary.*

THE THEORY OF RELATIVITY*

By Andrew H. Patterson

The idea of Relativity is not new. It was presented by the old philosophers, and has been a constant part of philosophical doctrine to this day. All of our knowledge is relative. Especially is this true of our knowledge of time and space. We know time only at a certain place; we observe the position of a point only at a certain time. To say that an observation or measurement was made at a given time is useless and meaningless until we have stated the place,—Greenwich or Washington or Tokio,—to which the time is referred. Places of stars in the Nautical Almanac are given only for the epoch, or time, stated at the head of the page, and corrections must be applied for later dates. It is quite true to say that we do not know the exact place of a star unless we know the exact time. Important dates in Assyrian history have been fixed because of the record of a total eclipse of the sun which was seen in the streets of the city of Nineveh at half-past nine on a certain morning of a certain month of a certain year in the reign of Jeroboam the Second. By calculating when this eclipse must have occurred at that particular place at that time of the morning, we at once link up the Assyrian era to our own, and can translate their time into ours. Time without position in space has no more independent existence than the direction "vertically upwards", for example, which changes with every point on the earth's surface.

But to fix the place of a point we need a system of axes to which we can refer its position by means of co-ordinates. The latitude and longitude of a ship are the two co-ordinates which fix its position on the surface of the ocean. If the point is to be fixed in *space,* three co-ordinates are needed, and if we can conceive of a four-dimensional space, four co-ordinates will be necessary to specify the position of any point therein.

It is immaterial whether we choose rectangular axes, or oblique axes, or whether we use polar co-ordinates or some other system, provided that the position of the point arrived at by any system is the same. Again, we can transform the co-ordinates of a point in one system of axes into its co-ordinates in another system of axes by appropriate mathematical operations, and since a line is a series of points,

* Presidential Address, delivered before the North Carolina Academy of Science, at the North Carolina State College of Agriculture and Engineering, Raleigh, April 30, 1920.

we can also transform the equation of a line with reference to one set of axes into another equation representing the same line referred to another set of axes. The only criterion for the validity of such a transformation is that the length, curvature and position of the line as given by the two equations, each referred to its own set of axes, shall be the same. And this point is to be emphasized: while we may not be able to conceive of a four-dimensional space, the mathematicians find no difficulty in getting the appropriate equations referred to four rectangular axes, and of course containing four co-ordinates, and these equations are as mathematically true and consistent as though we habitually used four dimensions in ordinary life.

But in using a set of axes, they must either be fixed, or else their position and motion must in turn be referred to some so-called "frame of reference" that *is* fixed, and the attempt to find such a frame of reference led to the modern theory of Relativity. Of course the earliest use of co-ordinate systems was in connection with Astronomy, and the first frame of reference was the supposedly fixed Earth, which Ptolemy, the Alexandrian astronomer who lived in the second century A. D., believed to be the center of a universe of planets and stars which revolved about it, and he referred their positions and motions to the stationary earth as his frame of reference. It is true that four hundred years earlier Aristotle and Aristarchus pointed out that by the laws of relative motion the movements of the celestial bodies could be equally well explained by a stationary sphere of stars and a revolving earth, but the learned men of the succeeding centuries followed Ptolemy, and it was not until the middle of the sixteenth century that Copernicus put forth again the theory that the starry sky, or "eighth sphere", should be considered at rest, and the sun also as its motionless center, while to this fixed frame of reference should be referred the motions of planets, comets, earth and moon. But since this transformation of axes—this change in the frame of reference—involved the demotion of the earth from its former proud position of center of the universe to a modest place among the minor planets, Copernicus' theory was bitterly opposed by theologians, both Protestant and Roman, on the idea that the new order involved great danger to the teachings of the church. Martin Luther denounced Copernicus roundly as an "upstart astrologer" who showed a lack of "public decency" in maintaining that neither the sun nor the "eighth sphere" revolved about the earth. But the new theory had come to stay, for it explained

clearly and simply the cause of the loops in the paths of the planets, the phases of Venus and the Moon, and the motions of planets, satellites and comets.

It led very soon to the discovery of Kepler's laws and the epoch-making work of Newton, including the development of the Newtonian mechanics and the differential and integral calculus. Two hundred years after Copernicus, Herschel again upset our frame of reference, for he showed that the whole Solar System is moving through space with a velocity of something like fifteen miles a second in the approximate direction of the star Vega, and that in addition the "fixed stars" are anything but fixed. All of them seem to be travelling in different directions through space with enormous velocities. One of them, indeed, No. 1830 in Groombridge's catalogue, has such a large proper motion that it is called the "runaway star."

So our fixed frame of reference again fails us, and in our attempt to find another we adopted the theory of a stationary ether filling all space, and affording the medium in which light waves are propagated. Such a medium seemed necessary to explain the experiments in optics, electrostatics, magnetism and electromagnetism, and since the same kind of medium with the same properties was needed for the explanation of phenomena in each of the branches of physics just named, Maxwell pointed out that this fact constituted strong evidence for the existence of the ether.

Now *if* it does exist, and *if* it is stationary in space, and *if* we can determine the absolute motion of the earth with respect to it, then we shall have found our much-desired frame of reference fixed in space.

The early experiments seemed to show that the ether is really at rest in space. In 1727 Bradley discovered the aberration of light, and the velocity of light as calculated from his formula agreed well with that found fifty years earlier by Roemer from observations of the eclipses of Jupiter's satellites. Now since the fact of aberration seems inexplicable on any other basis than a fixed or stationary ether, because if the ether in the telescope tube travels with it there would be no reason for any aberration, it was considered that the aberration of light clearly indicated that the ether is at rest in space, and that the material composing the earth moves through the ether just as a tennis racquet moves through air, allowing it to flow through the holes in the stringing. But it seemed incredible that any medium could stream

through the interstices in and between molecules in the solid earth at a rate sometimes of more than thirty miles per second without showing the least sign of friction or binding of any kind, and so further experiments were made. Airy tried the aberration experiment with a telescope tube filled with water, and expected to see an increased aberration, because the velocity of light in water is only three-fourths of what it is in air, and according to the aberration formula the less the velocity of light in the telescope tube the greater the angle of aberration should be.

But when Airy measured the angle through which the water-slowed light was deflected, he found it exactly the same as Bradley had found for full-speed light! This was a puzzling thing, to be explained only on the theory that the water dragged the ether along with it, with a velocity sufficient to compensate exactly for the change expected in the angle from the diminished velocity of light. Time is wanting to detail the experiments of Fizeau, Fresnel, and others to settle this point, but they showed apparently that something of the kind does take place, —a sort of entrainment or cling or viscous drag of the ether,—and they strengthened enormously the conviction that the ether does exist, is a substantial medium, and can be affected by matter,—that is, dragged along.

This brings us to the celebrated experiment of Michelson and Morley, which was an attempt made in 1881, and subsequently repeated, to measure the absolute speed of the earth with respect to the stationary ether of space. They certainly had a right to expect success, for they took every precaution to ensure it. The experiment consisted in splitting a ray of light, sending one-half in the direction of the earth's motion through space, then reflecting it by a mirror back to the source, while the other half of the ray is sent at right angles to the line of motion of the earth, and is then similarly reflected back, the two reflected rays interfering to produce interference bands in an interferometer, invented by Michelson.

The distance from the source to each mirror is exactly the same, but the distance the light travels to and fro between the mirrors and the source is *not* the same when the earth is in motion, being greater in the line-of-motion direction than in the direction at right angles to it. The mirrors and other instruments were mounted on a heavy stone slab floated in mercury, and they expected that when the apparatus was turned through a right angle so that what was before the longer

line-of-motion system became the shorter thwartwise system, they would see the interference fringes in the interferometer move to the right or left. But nothing of the kind happened, and the inevitable conclusion was that there is no appreciable relative motion between the earth and the ether,—that is, that the earth drags the ether in its vicinity along with it at full earth-velocity!

But if so, how can we explain the Airy experiment with the water-filled telescope, where the ether seemed to be dragged with a velocity less than half that of the earth? And especially should be asked, how shall we explain the aberration of light, which seemed to show that the ether isn't dragged along at all? Yet undoubtedly the Michelson-Morley experiment seems to indicate that the whole earth is surrounded by an envelope of stagnant ether, at rest with respect to the earth. This is absolutely contradictory, and physicists lost no time in making further tests.

Lodge spun a huge double disk of steel with tremendous velocity, and sent a split ray of light around in a groove between the two disks, half in one direction, half in the other. If the discs dragged the ether in the narrow groove around with them, the two half rays, one going with the dragged ether, the other against it, ought to interfere and produce fringes. Again no effect. Mascart and others devised most beautiful and accurate tests, but all of them gave negative results. In short, as Lodge says: "Interference methods all fail to display any trace of relative motion between earth and ether." Wood sums it up as follows: "Every experiment, with the exception of the one performed by Michelson and Morley, is in accord with the hypothesis of a stationary ether,"—that is, an ether perfectly stationary in space.

But how then can we explain the negative result of the Michelson-Morley experiment? Certainly interference methods are the most accurate and sensitive we have in the science of optics, and if they fail to detect relative motion between the moving earth and the fixed ether how can we believe that it exists? Lorentz and Fitzgerald then came independently to the conclusion that a moving piece of matter contracts in the direction of its motion. While this contraction is small,—less than three inches in the case of the earth's diameter in the direction of its orbital motion,—yet it would account exactly for the negative result of the Michelson-Morley experiment, because the longer path of the light parallel to the line of motion of the earth

might, by contraction of the stone slab, become exactly equal to the thwartwise path, and if so, no displacement of the interference fringes would result. Besides, this contraction is to be expected, anyhow, on the basis of the electron theory of matter, and in just the amount necessary to explain the negative result of the Michelson-Morley experiment. Tests were then made with wood and steel beams, in place of the stone slab, and it was found that they apparently contracted in the same manner and to the same extent, so we conclude that all matter behaves in the same way. But if such a contraction takes place in crystals, it looks as though double refraction should take place in them. This was tried by Lord Rayleigh and by Brace, but again with a negative result.

It seemed as though all the forces of nature were in a conspiracy to defeat our efforts to find a fixed frame of reference, and the determination of the absolute velocity of the earth with reference thereto, so that after all our work and experimentation it must be admitted that we have but the slightest real idea of either the magnitude or direction of our motion through space, though it would be of the first importance to us in astronomy and physics if we could only know it.

Now we come to the Einstein Theory of Relativity, which was at first an attempt simply to explain the negative results of the Michelson-Morley experiment. We must clearly distinguish three steps or stages in the development of this theory: (1) the Special Relativity theory; (2) the General Relativity theory; and (3) the latter theory as applied to gravitation, or the Einstein Theory of Gravitation.

To aid us in understanding the theory of Relativity, let us recall a few of the results attained in the development of Newtonian mechanics, on which we have built confidently the entire structure of modern physical science. (Of course the Newtonian mechanics, in its turn, is founded on Euclidean geometry, with its dozen axioms and postulates and its three-dimensional space.) In our search for the fundamental, bedrock conceptions, we have adopted, following the lead of Newton, those of Length, Mass and Time, as separate and distinct ideas, independent of each other, and perhaps capable of absolute measurement. For these we have adopted as our fundamental units the centimeter for length, the gram for mass, and the second for time, giving us the centimeter-gram-second or c.g.s. system of units. We have attempted to base all other ideas, such as force, work, energy, etc., on these as derived ideas, and we call their units derived units.

For example, the notion of velocity implies that a certain *length* of path is traversed in a certain *time*, and so by dividing the length by the time we get the *rate of motion*, which is the derived quantity we call velocity. Hence the dimensional formula, so-called, of velocity, is L/T. In the same way we can express every physical quantity in terms of a dimensional formula involving L, M, and T, except a few which we have been obliged to express partly in quantities just as fundamental as any others,—namely, temperature, magnetic permeability and specific inductive capacity.

In addition we have grown accustomed to accept without question Newton's laws of motion, and his inverse square law of gravitation, and we never doubted the unchangeable character of mass. We believed that a quantity of matter had the same mass and inertia under any and all conditions of place, time and velocity. We could change its weight, but not its mass, and this is the law of Conservation of Mass.

It is true that in 1881 J. J. Thomson, a rising young physicist, newly appointed head of the Cavendish Laboratory at Cambridge, showed mathematically that an electric charge in motion took on additional mass, but as its velocity had to be very great,—twenty thousand miles per second and upwards,—before this extra mass, or quasi-mass, became appreciable, his work had only a theoretical interest, because up to 1897 the highest velocity ever reached by matter, so far as we knew, was that of the great comet of 1882, and that was only four hundred miles per second at the perihelion point of its orbit. In 1897, however, Thomson's theory of the dependence of mass upon velocity suddenly became of the highest interest, because he not only found a way to measure the enormous velocity of flying electrons in a vacuum tube, but also of measuring their charge and their mass, and by developing this method Kaufmann, Bucherer and others proved by measuring the mass of electrons at various speeds that Thomson was quite right in his theory, and that *mass does depend upon velocity.* It follows, therefore, that the mass of a body in the direction of its motion is different from its mass in a transverse direction, and hence arose the idea of longitudinal and transverse mass. Thus a body may have two values of its mass at the same time, —truly a wide departure from the old Newtonian idea.

The whole mass of any body at rest is now supposed to be due to *the motion and the energy content* of its component parts,—elec-

trons, atoms and molecules,—while if the body itself is in motion an additional mass is given to it in the direction of motion. A shell weighing one ton will have an additional mass of one-millionth of a gram when fired with a muzzle velocity of 2,500 feet per second. For small speeds, therefore, the increase of mass is inappreciable, but for speeds of more than 100,000 miles per second the mass rapidly increases until at the velocity of light, which is 186,000 miles per second, the mass of a body would be infinite. The electrons inside an atom, and the rays fired off from radium, do actually reach prodigious velocities,—more than 100,000 miles per second.

But if mass is a function of velocity it is not a fundamental quantity, and cannot have an independent existence, so it must be given up as one of the pillars of the temple of science. Now comes Relativity and shows that determinations of both length and time also depend upon velocity, so they do not have an independent existence either, and two more pillars of the temple fall, irretrievably, because the determination of absolute velocity is forever beyond our reach.

Thus we have our first experience with the realm of Relativity,—the land of Topsyturvydom. We have our three *fundamental* conceptions of Length, Mass and Time all depending upon a *derived* conception, Velocity, which we formerly held to be dependent upon them! And then, having pointed this out, the relativist quietly states that all such experiments as that of Michelson and Morley are bound to fail, because it is impossible to determine the absolute velocity of the earth through the ether by experiments made on the earth, and besides, there isn't any ether anyhow! To the first statement we reply that we are on the earth, and can't get anywhere else, so if we cannot determine the velocity of the earth by experiments made here we can never know its velocity, and never be able to fix a unit of absolute motion. To which the relativist retorts, "Quite right,—we never can," and this is the First Postulate of Relativity.

To the second statement, that there is no ethereal medium, we can only ask what takes its place, to which the relativist replies, "No medium at all; electromagnetic energy, including light, is propagated through space somewhat as water is thrown from a hose. It is self-existent, and needs no medium." When we examine this remarkable statement, we should have as the background of our thinking the facts concerning the ether theory, which are, briefly, these: When the assumption of the existence of the ether was made, to explain the phe-

nomena of optics, electrostatics, etc., attempts were made to measure its properties. Newton thought its density was something like 700,000 times less than that of water; Lord Kelvin thought the ether so attenuated that it had a density of only one-quintillionth that of water, and many other scientists agreed with them as to the extreme tenuity of the ether. On the other hand, Sir J. J. Thomson says that "all mass is mass of the ether; all momentum, momentum of the ether; and all kinetic energy, kinetic energy of the ether," which shows the confidence of the foremost English physicist in the reality of the ether, but he goes on to say that this view "requires the density of the ether to be immensely greater than that of any known substance." Other leading physicists take this view also, and Sir Oliver Lodge insists that the ether has a mass of one quadrillion grams per cubic centimeter, and that "compared to ether the densest matter, such as lead or gold, is a filmy gossamer structure like a comet's tail"!

Now we all agree, I am sure, that when Kelvin claimed that one cubic centimeter of the ether weighs one-quintillionth of a gram, and Lodge says it weighs one quadrillion grams, (which is one million tons), there is a serious discrepancy, to say the least, in the estimates of physicists as to the properties of the ether, and we are not surprised to learn that there are a multitude of ether theories,—solid, liquid, elastic, labile, irrotational, gyrostatic, adynamic, etc., so no wonder Relativity wants to get rid of the whole thing by turning the ether out of doors.

And yet there comes, in protest, the cool reasoning of one of our very foremost American physicists, Millikan, who says that the ether "was called into being solely for the sake of furnishing a carrier for electromagnetic waves, and it obviously stands or falls with the existence of such waves in vacuo, and this has never been questioned by anyone, so far as I am aware." Other leading physicists protest also against giving up the notion of the ether for what Newton called "the forlorn idea" of empty space, among them being Lorentz, the great Dutch mathematician and physicist.

But Planck, the originator of the Quantum Theory, gives up the ether, and Einstein of course does the same, for his first postulate implies this very thing. But his second postulate states that light in a vacuum is propagated with a constant velocity quite independent of the velocity of its source, and queerly enough, this postulate seems to assume the existence of the ether, which the first postulate denies,

or as Stewart says, "we have the Principle of Relativity destroying a concept which is used in one of its postulates,"—another instance of Topsyturvydom.

Einstein admits this, but cannot get away from the confidence he, and all other physicists, have always had in Maxwell's great theory of electrodynamics, and the equations in which it is expressed, and so Einstein states in his London "Times" article that for this reason he was led to achieve the logical reconciliation of his two postulates by making a change in the doctrine of the physical laws of time and space. In doing so, however, he was obliged to overthrow some of the time-honored ideas of Galileo and Newton, and deal with four-dimensional, instead of three-dimensional space. Of course that also meant using non-Euclidean mathematics, and the difficulties pressing upon him from every side seemed insuperable. But he was immensely helped by the work of Minkowski, who developed a system of four dimensions,—using time for the fourth dimension,—involving four rectangular axes, of which three are for the three space dimensions, and the fourth is the time axis. Space and time are thus bound together, and no mathematical difference is made between them, the axes being interchangeable.

It is of course impossible for us to conceive of four dimensions all at right angles to each other, but let us take this example: When we go to the moving-picture show, we see the screen picture in only two dimensions, of course. But we supply a third dimension in our minds by seeing the perspective of the picture. We see a horseman coming in the distance apparently straight towards us, along the third axis which our mind supplies perpendicular to the screen. But there is another element in the picture, the *time* element. Time is always of the essence in melodrama. The interest centers in the question as to whether the hero, beset with difficulties and dangers, as he always is, will be in time to rescue the fair heroine. This *time* element, measured along an imaginary time axis, is also mentally present, and the picture is not complete without it. And moreover, as stated before, while we cannot visualize this axis at right angles to the others, the mathematician can make his equations behave exactly as though we could.

What Tennyson calls our "bourne of time and place," therefore, Minkowski calls a four-dimensional "space-time continuum," and by using four-dimensional geometry he showed *how events in nature may*

be represented mathematically, and how any equation referred to these four axes could be transformed to any other set of axes provided the second set is at rest or moving *uniformly* with respect to the first. Einstein used many of Minkowski's ideas, and developed what he calls his Special Relativity Theory, which he describes as follows: The Special Relativity theory is the application to any natural process of the following propositions:

1. Every law of nature which holds good with respect to a co-ordinate system K must also hold good for any other system K′ provided that K and K′ are in uniform motion of translation.

2. The second proposition is that light has a constant velocity in a vacuum, quite independent of the velocity of its source.

There is much experimental evidence for the truth of this second postulate, and the special theory, resting only on the two postulates just given, was eagerly studied by physicists.

It was immediately seen that the most important fields of study were those of acceleration and energy. The conception that inert mass is nothing but latent energy was developed, the law of conservation of mass lost its independence and became merged with the law of conservation of energy, and new laws of motion, differing from Newton's, were worked out for masses moving with great velocity. Many startling and unexpected results were found, and Einstein pushed his investigations vigorously. Please remember that his *special* theory dealt only with axes in *uniform* motion, and he next tried to find a more generalized theory dealing with axes in *any* kind of motion. Again the obstacles in his path seemed to defy his highest skill. But he persisted, for he asked himself, why must the independence of physical laws with regard to a system of co-ordinates be limited to a system of co-ordinates in *uniform* motion of translation with regard to one another? What has Nature to do with the co-ordinate systems which *we* propose, or with their motions? We must, of course, use arbitrarily chosen systems to describe Nature's operations, but they ought not to be limited as to their *state of motion.* So he worked on until he found the necessary transformation formulae for *any kind of motion* of the axes, and this is what he calls his General Theory of Relativity, the single postulate of which may be stated as follows: The laws of nature must remain invariant for all transformations of co-ordinates. But he further says that "a generalized theory of

Relativity must include the laws of gravitation, and actual pursuit of the conception has justified the hope." So his third achievement is his new theory of gravitation, which differs widely in some respects from that of Newton. To understand it is not easy.

First, let me remind you that gravitation has always been a physical mystery, and numerous theories to account for it have been developed without success. For one thing the speed of gravitation seems to be infinite, the only thing in nature which has a speed greater than light. Again, we say the sun "attracts" the earth and holds it in its orbit, but when we find that this so-called attraction is a force sufficient to break a million millon rods of the best tensile steel, each seventeen feet in diameter, we are amazed that any ethereal medium can transmit it. And if we let the ether go, we are still more perplexed. Let us, however, start with the conception that all pulls are really pushes. When lemonade is sucked or pulled through a straw, it is really the pressure of the atmosphere which pushes it through the straw from the other end. Perhaps gravitation is a push, rather than a pull.

When a baseball curves, we do not imagine something pulling it around in a curve, but we think of the bank of air in front and on the side of it, due to its twisting motion, as pushing it around. In like manner a railroad train is pushed by the reaction of the outer rail around the curve in the track. So we may imagine gravitation as pushing the earth around in its curved orbit. From this conception let us proceed to another,—the principle of Least Action. It may be familiarly expressed in this way; every moving body holds to the line of least resistance. That is what the curving baseball does; perhaps that is what the curving earth does. If so, the first thing to ascertain is what the line of least resistance is in space, and why it is so, if we can; at any rate, find out what a body will do, and how it will move under certain conditions.

This Einstein has done, and as he worked he came more and more to the conclusion that the idea of gravitation, like the ideas of time and space, is only part of the mental scaffolding we have erected to explain the phenomena of nature, and has no existence apart from our brains. To understand this let us imagine ourselves in an elevator high up in the Woolworth building. We feel the weight of our bodies pressing the soles of our feet; we feel the weight of the package we are carrying; perhaps a pendulum is swinging in the elevator. Then

suppose the wire rope breaks; the elevator with its contents falls vertically with the gravitational acceleration of thirty-two feet per second per second.

If we could keep our mental equilibrium under the circumstances, we would notice that our weight appeared to vanish; that the package we carried also lost its weight, and if we removed our hand from it, it would remain suspended in mid-air; the pendulum, if at the end of its swing when the rope broke, would remain there motionless and would not swing back. In other words, so far as we are concerned, and so long as the elevator is falling, gravity has been annihilated by giving the appropriate acceleration to the elevator. In reality, an observer inside a closed windowless box could not by any means decide whether the box is in a static gravitational field, or is endowed with accelerated motion in a space free from gravitation. We seem to weigh more while in an elevator *ascending* with accelerated motion, so that acceleration simulates gravitation and may be substituted for it. Now imagine two sets of four-dimensional axes, one set stationary in the Woolworth building, and the other set fixed in the falling elevator. Let x, y, z, and t be the co-ordinates of a point with reference to the second, or falling-elevator set of axes. Then, since we have no gravitation in the elevator to complicate matters, an element of length *ds* with reference to this set would be given by the equation

$$ds^2 = dx^2 + dy^2 + dz^2 + dt^2$$

Now let the same point mentioned above have at the same instant the co-ordinates x′, y′, z′ and t′ with reference to the first, or fixed-in-the-building set of axes. Then the transformation equation for *ds* will be

$$ds^2 = g_{11}dx'^2 + g_{22}dy'^2 + g_{33}dz'^2 + g_{44}dt'^2 + 2g_{12}dx'dy' + 2g_{13}dx'dz' + \text{etc.}$$

There are ten of these g coefficients, and their value depends on the nature of the transformation, *and specifies it*. They can be used, therefore, not only to specify it, but they also define *the original gravitational field, because they specify how it was got rid of.*

Now in Einstein's theory these ten g's, used in ten differential equations, are regarded as ten values of the gravitational potential specifying the field, and one of them, g_{44}, is approximately the same as the Newtonian potential, except for a factor.

Einstein, after long investigation, has so chosen his equations that they remain unaltered by any change of co-ordinates, and these ten are the only ones which do satisfy all conditions. What has just been said illustrates Einstein's famous "Principle of Equivalence," which states that for any particle at any instant it is possible to replace the effect of a gravitational field upon it by a mathematical transformation of axes.

If, therefore, gravitation can be annihilated mathematically by a transformation to an accelerated set of axes, and if its very existence depends upon a choice of axes, which is contrary to the General Relativity Postulate, then gravitation, in the words of deSitter, "becomes almost a property of space."

Of course a first approximation from Einstein's equations, neglecting terms of higher orders, gives the old Newtonian law for comparatively small velocities. Please notice, however, that Einstein's theory only shows how gravitation *acts*, not what causes it to act thus. It is in no sense an explanation of gravitation, which remains as much of a mystery as before. Now a new theory, like a tree, is known by its fruits, and when Einstein was asked to make his theory do things to prove its truth he was at first perplexed to find cases in which the actual differences between his theory and that of Newton could be subjected to observation.

But he was not long at a loss, and presented three cases which would test the correctness of his theory. The first case was the long outstanding discrepancy between theory and observation shown in the displacement of the perihelion point of Mercury's orbit. This point shifts around toward the east at the rate of 574 seconds of arc per century. The Newtonian mechanics, allowing for the effect of the other planets on Mercury's orbit, accounts for a shift of only 532 seconds, thus leaving an unexplained shift of 42 seconds of arc per century. Einstein's theory calls for a difference of 43 seconds,—an almost startling agreement. But of course Einstein might have started with this answer, and worked backwards, as it were, to his equations, so a great deal more interest was taken in his second case: a prediction that at the eclipse of the sun on May 29, 1917, the light of certain stars which just grazed the sun on its way to the earth would be found to have a deviation from a straight path because of the sun's gravitational field which he estimated would amount to 1.75 seconds of arc.

This prediction was made in 1917, two years before the eclipse, and Einstein was a professor in a German university, shut in by the war, and so helpless to test the observation himself, but the English promptly began to make plans for sending out not one but two eclipse expeditions to test the theory. Let us examine the point in question. For years it has been customary to regard light as having mass, for we reasoned as follows: Light is a form of energy; being of the kinetic type it is expressed mathematically in terms of its velocity and its mass, or at least something that takes the place of mass and acts like it. Now if light possesses mass and velocity it must possess momentum, and ought to exert a push when it falls on a body. This light pressure, or radiation pressure, was predicted by Maxwell, and its value calculated by him, but it was only experimentally confirmed forty years later by Nichols and Hull and Lebedew. It is the radiation pressure from the sun which causes a comet's tail to stream behind the comet when approaching the sun, and to stream ahead of the comet when receding from the sun.

The question next arises, does light possess weight? Is the mass of light the kind which is acted on by gravitation? If so, we can consider a beam of light passing near the sun as a comet, and using the regular comet formula we can regard the speed of light as the speed of the comet, and as usual insert the proper value of nearest approach to the sun. From this formula we can find the angle between the asymptotes of the cometary orbit, and hence find the angle of deviation of the ray which we should expect on the basis of Newtonian mechanics. The result is an angle of .82 seconds of arc. Now in the case of ordinary comets we have always found that their speed increases while they are approaching the sun, and decreases after they have swung round it on their long journey back into the depths of space, so Newton's idea was that this acceleration should be expected of any comet moving with any speed, and acted on by the sun's gravitation, because force always produces acceleration in a mass free to move.

And just here is one of the most interesting of Einstein's discoveries. It is shown from his formulas that if a body is approaching the sun with a velocity less than about 100,000 miles a second, it *will* be accelerated in its motion, but if it has a velocity greater than this amount *it will actually be retarded* as it moves toward the sun. Such a thing is inconceivable on the basis of Newtonian mechanics. Incon-

ceivable, yes, but is it true? Einstein worked out his predicted deviation of a ray of light grazing the sun on the idea that it *is* true,—that the ray does really suffer a retardation on its way toward the sun proportional to the increasing gravitational field of the sun. This would of course make the part of the wave front closest to the sun move more slowly than the remoter portion, and hence the ray would be swung round through an angle of 1.75 seconds of arc, as already mentioned, and this is *more than twice* the angle expected from Newton's laws. So here is a clear-cut test:—Newton or Einstein,—a deviation of .82 seconds of arc, or a deviation of 1.75 seconds. Which would it be? The two British eclipse expeditions sent out last summer, one to Sobral, in Brazil, and the other to Prince's Island, west coast of Africa, both detected the deviation, and in the required amount to show the correctness of Einstein's views.

This was the triumph which put Einstein's name on the front page of every newspaper, and made every physicist in the world prick up his mental ears and begin to study Einstein's work more closely.

The third test set by Einstein for his theory was this:—his formulas show that the inside mechanism of an atom moves more slowly in a gravitational field than in free space. Perhaps this is due to the retardation suffered by a particle moving with a prodigious velocity through a gravitational field, as considered above. At any rate, Einstein predicted that light waves coming from a source located in an intense gravitational field would make a spectrum in which the lines would be shifted toward the longer-wave end of the spectrum, which is the red end.

This effect was looked for without success, but Einstein remained serene in his conviction that it would be found, and offered to rest the validity of his entire theory upon it.

Now comes his third triumph, for quite recently two young physicists at Bonn not only detected the shift towards the red end of the spectrum, but also discovered the reasons why previous attempts to find it, at Mt. Wilson and elsewhere, were unsuccessful.

These three triumphant verifications of the Einstein ideas about gravitation have focussed the eyes of the world upon this modest scholar in Berlin. Born a German Jew, he moved to Switzerland during his boyhood, was educated there, became a Swiss citizen and served for some years in the Swiss patent office. During this time he pursued his mathematical studies, and later taught in the Zurich Poly-

technikum, from which he went to the University of Prague. Just before the war he was called to the University of Berlin, at the age of forty. He did not sympathize with the militarists and protested vehemently against the famous, or rather infamous, manifesto of the German professors in 1915. His frank statement expressing his thanks to the English government and to his "English colleagues" for going to so much trouble and expense to verify his predictions, when he was himself helpless to do so, shows a fine spirit, and has gained for him both admiration and respect. It was, in part, as follows: "It was in accordance with the high and proud tradition of English science that English scientific men should have given their time and labor, and that English institutions should have provided the material means, to test a theory that had been completed and published in the country of their enemies in the midst of war."

Some of the more mathematical and theoretical conclusions drawn from his equations may be interesting. If a circle be imagined in empty space, its circumference bears to its diameter the usual ratio of 3.14159 to 1, but if a heavy mass be placed at its center, the ratio of circumference to diameter is changed, because of a "warp in space" produced by the mass. Again, suppose a wheel is rotating in space. The rim of the wheel, because it is at every point moving in the direction of its length, suffers the contraction already explained in connection with the Michelson-Morley experiment, but the *spokes* of the wheel are not moving in the direction of their length, and hence do not suffer contraction. Here again the circumference of the wheel changes length while the diameter does not, so the ratio is again not the usual one. This same contraction in the direction of motion is suffered by electrical, optical and gravitational fields. If a system is moving with respect to us, the unit of time in the moving system seems longer to us than to an observer on that system, and when the system is moving with respect to ours with the velocity of light, their second would seem infinitely long to us. That is, if we could watch a clock face on a system receding from us with the velocity of light, although an observer on the system with the clock would see it running as usual, we would forever see the clock hand at exactly the same point.

This sounds as crazy as anything in "Alice in Wonderland," and in fact the Mad Hatter must have been the originator of Relativity, and to have had this very point in mind when he claimed that for

him it was always six o'clock and always tea-time. Einstein goes even farther than this; let me quote his own words: "We could substitute for the clock a living organism enclosed in a box. Were it hurled through space like the clock it would be possible for the organism, after a flight of whatever distance, to return to its starting point practically unchanged, while an exactly similar organism which remained motionless at the starting point might have given place to new generations. For the organism in motion, time was but a moment, if its speed approached the velocity of light." This statement implies that not only does time depend on velocity, but that the rapidity of chemical and biological processes is also a function of velocity.

Rosalind's remark is therefore doubly true, that "Time travels in divers paces with divers persons," and until the velocity of each system is known (that is, the relative velocity, for we can never find the absolute velocity of any system,) we cannot know with whom the swift foot of Time ambles, trots, gallops, or even stands still withal. One observer's *now* may be another observer's *future* and a third observer's *past,* all at the some cosmical moment of time. Two actions quite simultaneous to one observer may not be simultaneous to another observer located in a different system. Again, what to a stationary observer is an electrostatic field is to a moving observer an electromagnetic field.

According to Einstein and Minkowski any point relatively at rest in space really traces a "world-line" or "path of adventure" parallel to the time axis. The locus of a point in relative motion is a line making an angle with the time axis. An observation is the crossing of two or more world-lines, and we know nothing of these world-lines between the points of crossing with other world-lines. The axes of our four-dimensional space-time continuum have been aptly called the to-and-fro axis, the forward-and-backward axis, the up-and-down axis and the sooner-and-later axis, the last, of course, being the time axis. On one side of the origin the time axis represents the past, on the other side the future. Events do not happen,—they are coincidences of world-lines, and are simply there, to be met or happened upon, as it were. A few years ago Anderson's new star burst forth. Whatever caused it is supposed to have occurred about the year of George Washington's birth, but we only happened upon a crossing of its world-lines with ours one hundred and seventy years later. If a change is made in an element of our system, it alters the whole past,

mathematically speaking, as well as the future. This seems absurd, and corresponds to nothing real in our experience, so far as we know, but these equations we are discussing have proved true in so many ways that we eagerly anticipate their further interpretation. New tests for straightness of lines, for simultaneity of events, etc., have been adopted, and everything seems queer and unfamiliar. Straight lines, according to Relativity, appear crooked to us, and vice versa. Spheres in motion become oblate spheroids, and we feel like the prisoner in Gilbert and Sullivan's opera, condemned always to play on a warped table, "on a cloth untrue, with a twisted cue, and elliptical billiard balls."

According to this theory, also, the *greatest possible* velocity in space is that of light,—186,000 miles per second. Even if a shell were fired with a velocity of 100,000 miles per second directly forward from a gun mounted on a car moving with the same velocity of 100,000 miles per second, the resultant velocity of the shell would not be 200,000 miles per second, as we should expect, but only 150,000. No combination of any number of velocities impressed upon a body can exceed the velocity of light. The new definitions of physical terms are equally puzzling, as for example: "Matter does not cause the curvature of space,—it *is* the curvature." Again, Einstein has practically ignored in his theory the idea of *force* as the condition for change of motion, which was possibly the greatest contribution made by Galileo to the science of dynamics, and in spite of the fact that some physicists hold force to be perhaps the most basic of all the ideas of mechanics. As already said, the ether, which Planck calls a "child of sorrow," is, in the eyes of relativists, hopelessly discredited.

The work of Einstein is epoch-making. Just as for sixty years everything in physics has had to square with Maxwell's equations,—even Einstein's theory,—so now there is already seen a tendency to make our thinking square with Einstein's equations. Just what results will come out of the new theory it is impossible to say. The Einstein mechanics have shown at least some power of exploration of intra-atomic space, which Newtonian mechanics could not do, and this may assist us in the development of a rational theory of atomic structure better than any theory we now have.

But we are not to stop here. The English are actively preparing to make even more accurate observations in Australia during the

eclipse of 21st September, 1922, when we may hope to have much additional light thrown upon the whole subject, which now presents, it must be confessed, many difficulties. For example, according to the new quantum theory energy is radiated in a discontinuous fashion in very small amounts called quanta. The value of a quantum has been determined, but according to the Relativity theory, since it travels with the speed of light, every quantum should appear infinite, which it doesn't.

Then, too, by no means all physicists agree with the theory, and Abraham, for instance, has opposed it vigorously, warning us against the "Sirenenklaenge dieser Theorie." Many others, such as Sir Joseph Larmor, while not hostile, are lukewarm. Trouton says that Relativity is merely trying to remove the lion in the path by laying down the general proposition that the existence of lions is an impossibility.

The truth is that the theory is so new, so revolutionary, and so difficult to understand, that the natural conservatism of science forces it to make its way slowly. Then, too, the language in which it is expressed in the articles scattered through the literature of the subject is not easily "understanded of the people." As an example, Larmor complains in one of his articles that a certain expression is only "wrapping up in abstractions the simple statement that when at any place the quadratic characteristic of the spatial extension involves the differential of the co-ordinate specially related to time in its product terms, then there is latent in it a specification of its own mode of change at that place with respect to uniform space-time." You see what a "simple statement" in non-Euclidean Relativity sounds like, and this may throw light on Einstein's reported saying that he did not suppose there were more than twelve men on the earth at present who can understand his theory fully. The surprising thing about this statement is that he should have put the number so high as twelve.

In conclusion, let us sum up the situation: Conservatives in science claim that at best Einstein has merely introduced some refinements in our mathematical weapons of attack; but the radicals claim that he has overthrown much of the older mechanics, has given the coup de grâce to the ether, and has started an entirely new chapter in the development of human thought comparable only to that begun by Galileo and Newton; furthermore, that the Relativity point of

view will color everything in the future, and that we have now two and only two foundations on which we can build with confidence,—the Electromagnetic Theory of Clerk Maxwell and the General Relativity Theory of Albert Einstein.

CHAPEL HILL, N. C.

A PARTIAL LIST OF BOOKS AND ARTICLES CONSULTED

Physical Optics. 2d. Edition. R. W. Wood, Chapters 24 and 25.

The Progress of Physics. A. Schuster.

Electrons. Oliver Lodge.

History of the Theories of Aether and Electricity. E. T. Whittaker.

Aether and Matter. J. Larmor. Chapter 2, Appendix D.

Electricity and Matter. J. J. Thomson.

The Ether of Space. O. Lodge.

Modern Electrical Theory. 2d Edition. N. R. Campbell

The Electron. R. A. Millikan.

Resume of Observations Concerning the Solar Eclipse of May 29, 1919, and the Einstein Effect. L. A. Bauer, Science, March 26, 1920.

Euclid, Newton and Einstein. "W. G.", Nature, Feb. 12, 1920.

The Theory of Relativity. A. C. D. Crommelin, Nature, Feb. 12, 1920.

Einstein's Theory of Gravitation. E. Cunningham, Nature, Dec. 4, Dec. 11, and Dec. 18, 1919.

The Recent Eclipse Results, and the Stokes Planck Ether. L. Silberstein, Phil. Mag., February, 1920.

Gravitational Deflection of High-Speed Particles. Leigh Page. Nature, Feb. 26, 1920.

The Ether vs. Relativity. Oliver Lodge. Fortnightly Review, January, 1920.

Gravitation and Light. J. Larmor. Nature, Dec. 25, 1919, and Jan. 22, 1920.

A New Conception of the Universe. A. J. Lotka. Harper's Mag., Feb., 1920.

Time, Space and Gravitation. A. Einstein. Educational Review, Feb. 1920.

Gravitation and the Principle of Relativity. A. S. Eddington. Nature, Dec. 28, 1916.

Elementarquantum der Energie. J. Stark. Physik. Zeitschr., Dec. 1, 1907.

Relativity in Astronomy. W. C. Rufus. Popular Astronomy, March, 1918.

Zur Elektrodynamik bewegter Koerper. A. Einstein. Ann. der Physik, 17, 1905, p. 891.

Relativitaet und Gravitation. A. Einstein. Ann. der Phys., 38, 1912, p. 1059.

Lichtgeschwindigkeit und Statik des Gravitationsfeldes. A. Einstein. Ann. der Phys., 38, 1912, p. 355.

Raum und Zeit. H. Minkowski. Phy. Zeitschr., 10, 1909.

The Principle of Relativity. E. Cunningham. Nature, June 11 and 18, 1914.

The Second Postulate of the Theory of Relativity. Q. Majorana. Phys. Rev., May, 1918.

Relativity. A. S. Eddington. Nature, March 7 and 14, 1918.

Presidential Address, Section A, British Association, 1914. F. T. Trouton, Nature, August 20, 1914.

Einstein's Theory of Relativity. Morris R. Cohen. New Republic, January 21 and February 18, 1920.

Applications of the Lorentz-FitzGerald Hypothesis to Dynamical and Gravitational Problems. H. A. Bumstead. Am. Jour. Sci., 26, 1908.

Relativity. D. F. Comstock. Science, May 20, 1910.

On the Theory of Relativity. R. D. Carmichael. Phys. Rev., Sept., 1912; Feb. and March, 1913.

The Second Postulate of Relativity and the Electromagnetic Emission Theory of Light. R. C. Tolman. Phys. Rev., 32, 1911, p. 148.

The Second Postulate of Relativity. R. C. Tolman. Phys. Rev., 31, 1910, p. 26.

On the Essence of Physical Relativity. J. Larmor. Sci. Am. Supp., No. 2253.

Relation of Mass to Energy. D. F. Comstock. Phil. Mag., 15, 1908, p. 1.

Fundamental Laws of Matter and Electricity. G. N. Lewis, Phil. Mag., 16, 1908, p. 705.

New Concepts of Time and Space. Claude Bragdon. Dial, Feb., 1920.

Acht Vorlesungen ueber Theoretische Physik. Max Planck, 1909.

Relativitaet und Gravitation. M. Abraham. Ann. der Phys., 38, 1912, p. 1056.

Relativity and Ether. Leigh Page. Ann. Jour. Sci., Aug., 1914.

Aether and Matter. Oliver Lodge. Nature, Sept. 4 and Sept. 25, 1919.

Physical Relativity. G. W. deTunzelmann. Sci. Am. Suppl., May 31, 1919.

Einstein's Law of Gravitation. J. S. Ames. Science, March 12, 1920.

Results of the Total Solar Eclipse of May 29. A. C. D. Crommelin. Nature, Nov. 13, 1919.

Relativity and Gravitation. O. Lodge and A. S. Eddington. Nature, Sept. 13, 1917.

Einstein's Third Victory. R. D. Carmichael. N. Y. Times, March 28, 1920.

Gravitational Deflection of High Speed Particles. A. S. Eddington. Nature, March 11, 1920.

Gravitational Shift of Spectral Lines. H. Jeffreys. Nature, March 11, 1920.

The New Relativity in Physics. R. A. Wetzel. Science, Oct. 3, 1913.

Attitude of the Newer Physics toward the Mechanical View of Nature. G. B. Pegram. Ed. Rev., March, 1911.

The Theory of Relativity. L. T. M. Nation, Apr. 11, 1912.
The Principal Concepts of Physics. W. F. Magie. Science, Feb. 23, 1912.
The Principle of Equivalence and the Notion of Force. C. A. Richardson. Nature, March 18, 1920.

A NEW METHOD FOR LAYING OUT CIRCULAR CURVES BY DEFLECTIONS FROM THE P. I.

By T. F. Hickerson

With Three Text Figures

The writer hopes that the tables based upon formulas given below will fill the long-felt need of a simple and time-saving method for laying out circular curves by deflections from the point of intersection of the tangents (the P. I.), thus avoiding the trouble of moving the instrument and resetting the vernier.

Referring to Fig. 1, P is any point on the circular arc CB and A is the point of intersection of the tangents. Also C is the point of curve (P. C.), and B is the point of tangent (P. T.). Lines from points A and O to point P makes angles of Θ and α with the line AO, these angles being plus when measured above AO and minus when below it. PN is drawn perpendicular to AO. The deflection angle is called Δ.

$$\text{Tan } \Theta = \frac{PN}{AN} = \frac{R \sin \alpha}{E + R - R \cos \alpha} = \frac{R \sin \alpha}{R (\sec \tfrac{1}{2}\Delta - 1) + R - R \cos \alpha}$$

$$\text{Hence, } \tan \Theta = \frac{\sin \alpha}{\sec \tfrac{1}{2}\Delta - \cos \alpha} \qquad \text{.....(1).}$$

Formula (1) shows that for a given value of Δ, the angle Θ is independent of the radius of the curve or the length of curve.

Imagine the curve divided into *ten equal parts*, then formula (1) gives the deflections to these points of division as follows:

$$\alpha = \tfrac{1}{10}\Delta, \tan \Theta_1 = \frac{\sin \tfrac{1}{10}\Delta}{\sec \tfrac{1}{2}\Delta - \cos \tfrac{1}{10}\Delta},$$

$$\alpha = \tfrac{2}{10}\Delta, \tan \Theta_2 = \frac{\sin \tfrac{2}{10}\Delta}{\sec \tfrac{1}{2}\Delta - \cos \tfrac{2}{10}\Delta},$$

$$\alpha = \tfrac{3}{10}\Delta, \tan \Theta_3 = \frac{\sin \tfrac{3}{10}\Delta}{\sec \tfrac{1}{2}\Delta - \cos \tfrac{3}{10}\Delta},$$

$$\alpha = \tfrac{4}{10}\Delta, \tan \Theta_4 = \frac{\sin \tfrac{4}{10}\Delta}{\sec \tfrac{1}{2}\Delta - \cos \tfrac{4}{10}\Delta},$$

$$\alpha = 0, \ \Theta_5 = 0,$$

$$\alpha = -\tfrac{1}{10}\Delta, \ \Theta_6 = -\Theta_4,$$

$$\alpha = -\tfrac{2}{10}\Delta, \ \Theta_7 = -\Theta_3,$$

$$\alpha = -\tfrac{3}{10}\Delta, \ \Theta_8 = -\Theta_2,$$

$$\alpha = -\tfrac{4}{10}\Delta, \ \Theta_9 = -\Theta_1,$$

$$\alpha = -\tfrac{5}{10}\Delta, \ \Theta_{10} = -\tfrac{1}{2}(180 - \Delta).$$

Values of Θ_1, Θ_2, Θ_3, etc., computed by means of the above formulas for different values of Δ show that they change *uniformly* with Δ; so that interpolation gives results as closely as 1 minute for ranges of 1° in Δ.

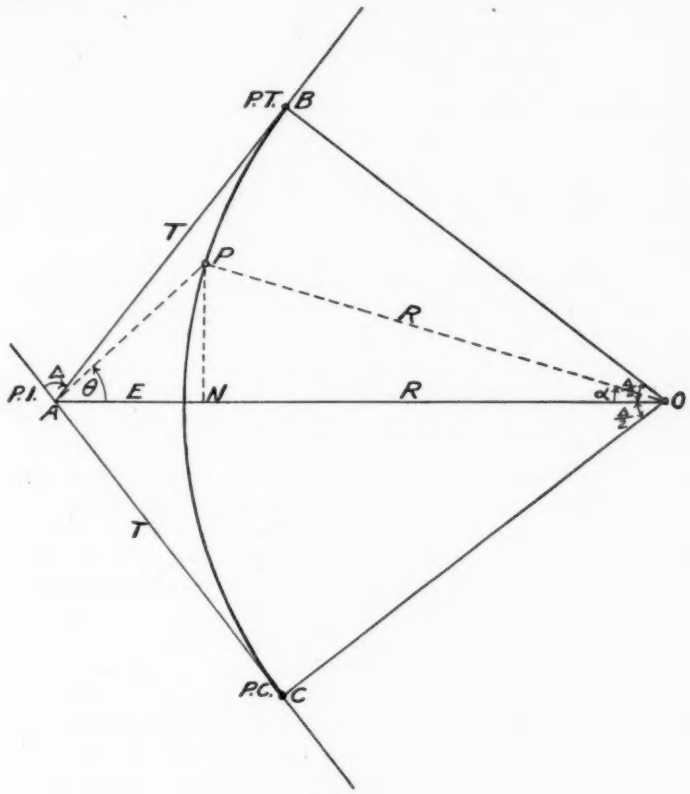


FIG. 1

For convenience in laying out curves without resetting the vernier, these directions to points on the curve are referred to the first tangent, the line CA produced.

Instrument at the P. I., and vernier reading $\Delta°$ on the P. T., we have:

Deflection to point (1) $= \Delta + \frac{1}{2}(180 - \Delta) - \theta_1 = 90° + \frac{1}{2}\Delta - \theta_1$,
(2) $= 90° + \frac{1}{2}\Delta - \theta_2$,
(3) $= 90° + \frac{1}{2}\Delta - \theta_3$,
(4) $= 90° + \frac{1}{2}\Delta - \theta_4$,
(5) $= 90° + \frac{1}{2}\Delta$
(6) $= 90° + \frac{1}{2}\Delta + \theta_4$,
(7) $= 90° + \frac{1}{2}\Delta + \theta_3$,
(8) $= 90° + \frac{1}{2}\Delta + \theta_2$,
(9) $= 90° + \frac{1}{2}\Delta + \theta_1$,
(10) $= 180°$.

It should be noted that the following pairs of deflections add up to $180° + \Delta°$; (1) + (9), (2) + (8), (3) + (7) and (4) + (6).

Using the above formulas, tables have been computed for all values of the deflection angle Δ varying by 1° from 3° to 128°. This covers all cases that are likely to occur in locating curves for roads and streets.

Fig. 2 is a graphical verification of the fact that for a fixed Δ, the deflections to the points of equal division on a curve remain constant for any length of the curve. This makes the method perfectly general.

The order of procedure in laying out a curve is as follows: (1) set up the instrument at the P. I., backsight on the first tangent with vernier reading O°, transit the telescope, unclamp the vernier and fix the line of sight on the second tangent, the vernier giving the deflection angle $\Delta°$; (2) decide what length of curve to use (determined usually either by the desired external distance E or the tangent length T); (3) compute T and E, using either the well-known table of tangents and externals for a 1° curve, or *preferably* the tangents and externals for a 100-ft. curve (Table II); (4) lay off the tangent length locating the end of the curve (the P. T.); (5) divide the length of curve by 10 and locate each of the ten points, or every other one, or every third one, etc., depending upon how many are needed to properly define the curve, by starting at the P. T., and getting the intersection of the end of the chord with the line of sight from the P. I., according to deflections read directly from the tables (Table I).

The middle point, or the 5th point of the curve, cannot be located very precisely by intersections, since the end of the chord would be moved in an arc tangent to the line of sight. This point can be located exactly by measuring the external distance E from the P. I., and this serves as a check. If only the 2d, 4th, 6th, 8th, and 10th points are located, then it is not necessary to know E.

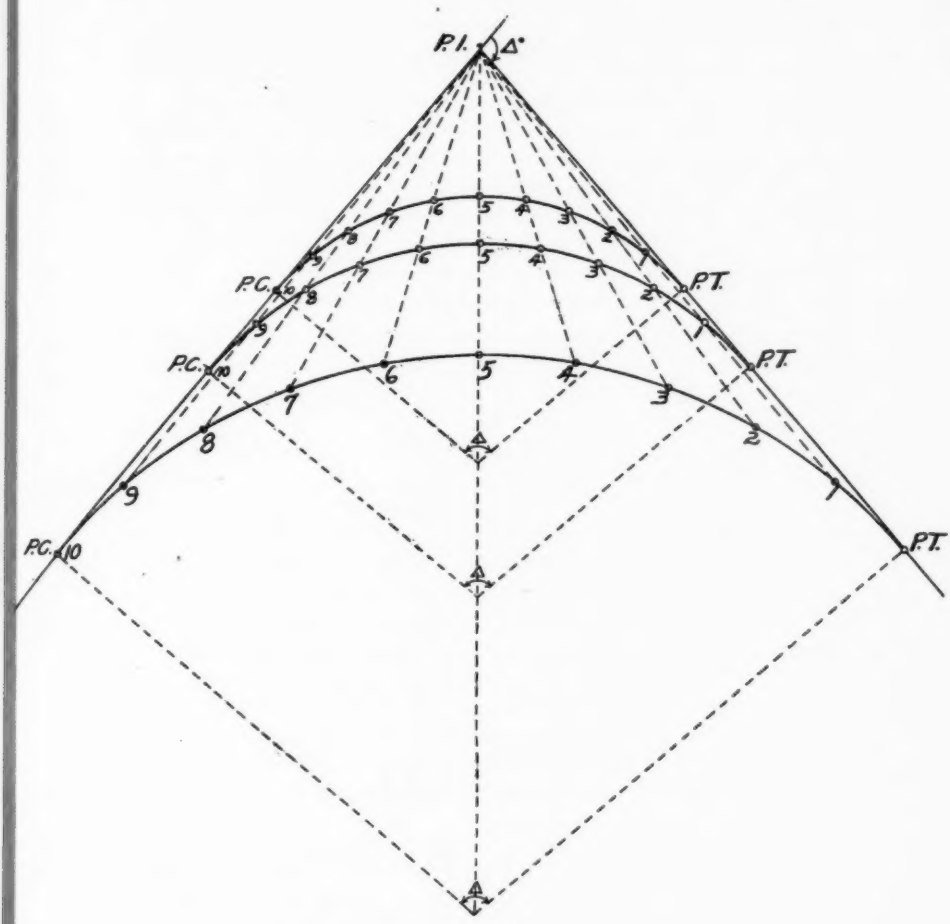


FIG. 2

The beginning of the curve (the P. C.) is located as the 10th point by a deflection which is always 180°. The station number of the P. C. is known, hence its location can be checked by measuring

the plus distance back to the preceding station. This method avoids measuring the tangent distance from the P. I., in order to locate the P. C.

It should be noted that the curve can be located by starting at the P. C. instead of the P. T., the deflection to the first point being the same as that to the 9th point as given by Table 1, etc.

If part of the curve is not visible from the P. I., say that beyond point 6, then the instrument may be moved to point 6 and the remaining points located by deflections from a preceding chord. Suppose a backsight is taken to point 2, vernier reading O°, then after reversing the telescope the proper deflection to locate point 7 is $\frac{5\Delta^\circ}{2 \times 10} = \frac{\Delta^\circ}{4}$, etc.

For very long curves in woods and at places where the P. I. is not accessible, the well-known deflection method should be used, that is, the instrument is moved to the P. C., and intermediate points on the curve.

During the past summer the writer was in charge of a party that surveyed 22 miles of federal-aid highways in hilly and mountainous country, and the following facts were observed: (1) not a single case of inaccessible P. I. occurred; (2) along 86 per cent of the curves the P. I. was visible throughout; (3) in only 42 per cent of the curves was the P. T. visible from the P. C. This means that 86 per cent of the curves could have been laid out completely with the instrument set only once (at the P. I.), whereas 58 per cent of them actually required the instrument to be set up three times. The first 11 miles was in fairly open country along the general direction of an old road. Here 96 per cent of the curves were visible throughout from the P. I., but 70 per cent of the P. T. points were not visible from the P. C. The other 11 miles of the survey was partly in a dense forest and not along an old road.

Aside from the time saved in not having to move the instrument, another step in the usual operation of laying out a curve is avoided, and that is, the tangent distance is not measured from the P. I., in order to locate the P. C. Curves laid out by the usual method begin and end with subchords of unequal length. This makes the deflections rather tedious to compute. The errors are cumulative, and the writer has seen the best of transitmen waste time in trying to find the little error that prevented the final check.

The resident engineer can more easily pick up the P. I., than any other point and he would find it convenient to realign the curve by deflections from this position while construction is going on, since it is apt to be beyond the grade stakes and not disturbed.

The points on the curve established by deflections according to the proposed new method are at equal and integral distances apart, but they are not full stations. The writer believes the advantages of full station points are largely imaginative. However, the chainmen can easily locate full station points on their return trip from the P. C. to the P. T., as is explained in Example 1. The middle ordinate of the equal chords can be found in Table III which has been compiled by the writer for the purpose. In this connection, it should be remembered that middle ordinates vary practically as the square of the chords; and for any chord, the ordinates vary practically as those of a parabola. See Fig. 3. Thus if the middle ordinate is 1 ft. the ordinate (or offset) at a point 2/5th of the chord-length from the end of the chord is 0.6 ft. The middle ordinate in practice is usually less than 1 ft. as will be seen later.

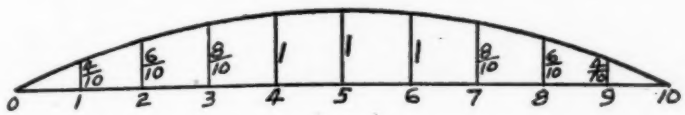


FIG. 3

Before proceeding with an illustration, Table II will be explained. This table gives the Externals, Tangents, Radii, and Degrees of Curve for circular Arcs of 100 feet in length according to values of the deflection angle ranging from 1° to 128°. It is offered as a substitute for the tables giving the functions of a 1° curve. The following formulas were used in computing the values in Table II:

$$D = \frac{100\Delta}{L} = \frac{100\Delta}{100} = \Delta,$$

$$R = \frac{5729.578}{D},$$

$$T = R \tan \tfrac{1}{2}\Delta = \frac{5729.578}{\Delta} \tan \tfrac{1}{2}\Delta,$$

$$E = R \tan \tfrac{1}{2}\Delta = \frac{5729.578}{\Delta} \operatorname{exsec} \tfrac{1}{2}\Delta,$$

For curves longer than 100 feet, the tabular values of the external, tangent, and radius must be multiplied, and the degree of curve divided, by the ratio of the given curve length to 100. For example, suppose Δ is 24° and the length of curve to be used is 400 feet, then

$$E = 5.334 \times 4 = 21.3,\ T = 50.744 \times 4 = 203.0,\ D = \frac{24}{4} = 6°,$$

$R = 238.8 \times 4 = 955.2$. This tables gives conveniently a length of curve that will always be a multiple of ten. The chords therefore will always be an integral number of feet in length.

Example 1.

Given $\Delta = 40°00'$; P. I at Sta. 62 + 11.8
From Table II, L = 100, E = 9.193, T = 52.135, D = 40°.

Suppose local conditions are such that E should equal 46 feet approximately. Hence, ratio $= \frac{46}{9.2} = 5$.

L = 500, E = 46.0, T = 260.7, D = 8°.
$\frac{500}{10}$ = 50 = length of each chord to be applied 10 times.

P. I. =	62 + 11.8
T. =	2 + 60.7
P. C. =	59 + 51.1
L. =	5
P. T. =	64 + 51.1

For $\Delta = 40°00'$, the deflections are given directly in Table I as follows:

Points		Deflections Δ
P. T.		
1st		40°29′
2d		42°29′
3d		47°58′
4th		63°41′
5th	(E = 46.0)	110°00′
6th		156°19′
7th		172°02′
8th		177°31′
9th		179°31′
10th	P. C.	180°00′

As a check in taking deflections from the table, it should be noted that the 1st + 9th = 2d + 8th = 3d + 7th = 4th + 6th = 180 + Δ = 220°00′.

The above points on the curve are not at full stations; but the chainmen, on their way back from the P. C., can very easily set stakes at full station and + 50 foot points as follows: the rear chainman holds the + 51.1 division of the tape at the P. C., and aligns the front chainman by sighting to the 9th point of the curve; then a right angle offset on the P. I. side of the curve, at a certain fraction (see Fig. 3) of the middle ordinate for a chord of 50 feet (see Table III), locates Sta. 60 (in this case the middle ordinate is 0.44 ft. and the offset is less than 0.1 ft.); next the rear chainman holds the zero end of the tape at Sta. 60 and aligns the front chainman by sighting from the 9th point to the 8th point, in order to locate Sta. 60 + 50 which is so near the 8th point it does not have to be shifted. The other stations are established in a similar manner.

Example 2.

Given Δ = 20°20′; P. I. at Sta. 37 + 18.2.
T = 50.532, E = 4.5 (Table II).
Suppose T = 100 = approx. desired length of tangent.
Ratio = 2, hence L = 200, T = 101.0, D = 10°10′.

P. I. = 37 + 18.2
T = 1 + 01.0

P. C. = 36 + 17.2
L = 2

P. T. = 38 + 17.2

$\frac{200}{10}$ = 20. Use 40-ft. chords applied five times.

Points	Deflections
P. T.	Δ °
2d	21°40′
4th	35°13′
6th	165°07′
8th	178°40′
10th P. C.	180°00′

2d + 8th = 4th + 6th = 200°20′. Check.

The quantities in Tables II and III are based on the definition that the "degree of curve" is the central angle subtended by an *arc* of 100 feet instead of a *chord* of 100 feet. The radius of a one-degree curve is found by means of the following proportion:

$1° : 360° = 100 \text{ feet} : 2\pi R \text{ feet, hence } R = \frac{36000}{2\pi} = \frac{36000}{2(3.14159)} = 5729.578$ feet.

The middle ordinate (M) of an arc whose central angle is $\alpha°$ and whose chord is c feet, is given by the formula:

$$M = R \text{ vers } \tfrac{1}{2}\alpha \quad \text{.....(4).}$$

$$\text{Also } M = \frac{c^2}{8\,R} \text{ approx.} \quad \text{.....(5).}$$

Formula (5) shows that for any radius, the middle ordinates vary as the square of the chords. The above formulas were used in computing Table III.

Assuming the arc to be parabolic, we have a convenient relation between ordinates at any point along the chord and the middle ordinate. See Fig. 3. For example, an ordinate at 8/10 of the chord-length from one end of the chord is 6/10 of the middle ordinate.

In practice, the middle ordinate is usually less than 1.0 foot, provided the chords do not exceed the limit where they vary more than .05 ft. from the arc. Table III shows these limits to be as follows:

100 ft.	chords	up	to	6°	curves;	middle	ordinates	up	to	1.31	ft.
50 ft.	"	"	"	16°	"	"	"	"	"	0.87	ft.
40 ft.	"	"	"	25°	"	"	"	"	"	0.87	ft.
30 ft.	"	"	"	37°	"	"	"	"	"	0.72	ft.
25 ft.	"	"	"	47°	"	"	"	"	"	0.64	ft.
20 ft.	"	"	"	67°	"	"	"	"	"	0.58	ft.
15 ft.	"	"	"	100°	"	"	"	"	"	0.49	ft.

TABLE I.

Deflections from the P. I. to Points of Equal Division along Circular Curves.

Pts.	Δ = 12°00′	Diff. 1′	Δ = 12°30′	Diff. 1′	Δ = 13°00′	Diff. 1′	Δ = 14°	Diff. 1′	Δ = 15°	Diff. 1′	Δ = 16°	Diff. 1′	Δ = 17°	Diff. 1′	Δ = 18°	Diff. 1′	Δ = 19°	Diff. 1′
1	12°00′	+1.00′	12°30′	+1.00′	13°10′	+1.01′	14°10′	+1.01′	15°11′	+1.01′	16°12′	+1.01′	17°13′	+1.01′	18°13′	+1.01′	19°14′	+1.01′
2	12°48′	+1.06′	13°30′	+1.06′	13°51′	+1.06′	14°56′	+1.06′	15°59′	+1.06′	17°03′	+1.06′	18°07′	+1.06′	19°11′	+1.06′	20°15′	+1.06′
3	14°41′	+1.22′	14°17′	+1.22′	15°53′	+1.21′	17°06′	+1.21′	18°19′	+1.21′	19°32′	+1.21′	20°44′	+1.21′	21°57′	+1.21′	23°10′	+1.21′
4	21°18′	+1.73′	22°10′	+1.71′	23°01′	+1.71′	24°44′	+1.69′	26°25′	+1.69′	28°06′	+1.67′	29°46′	+1.65′	31°25′	+1.64′	33°04′	+1.62′
5	96°00′	+0.60′	96°15′	+0.60′	96°30′	+0.60′	97°00′	+0.60′	97°30′	+0.60′	98°00′	+0.60′	98°30′	+0.60′	99°00′	+0.60′	99°30′	+0.60′
6	170°42′	−0.73′	170°59′	−0.71′	169°59′	−0.71′	169°16′	−0.69′	168°35′	−0.69′	167°54′	−0.67′	167°14′	−0.65′	166°35′	−0.64′	165°56′	−0.62′
7	177°19′	−0.22′	177°13′	−0.22′	177°07′	−0.21′	176°54′	−0.21′	176°41′	−0.21′	176°28′	−0.21′	176°16′	−0.21′	176°03′	−0.21′	175°50′	−0.21′
8	179°12′	−0.06′	179°10′	−0.06′	179°09′	−0.06′	179°05′	−0.06′	179°01′	−0.06′	178°57′	−0.06′	178°53′	−0.06′	178°49′	−0.06′	178°45′	−0.06′
9	179°51′	−0.00′	179°51′	−0.00′	179°50′	−0.01′	179°50′	−0.01′	179°49′	−0.01′	179°48′	−0.01′	179°47′	−0.01′	179°47′	−0.01′	179°46′	−0.01′
10	180°00′	0.00′	180°00′	0.00′	180°00′	0.00′	180°00′	0.00′	180°00′	0.00′	180°00′	0.00′	180°00′	0.00′	180°00′	0.00′	180°00′	0.00′

Pts.	Δ = 20°	Diff. 1′	Δ = 21°	Diff. 1′	Δ = 22°	Diff. 1′	Δ = 23°	Diff. 1′	Δ = 24°	Diff. 1′	Δ = 25°	Diff. 1′	Δ = 26°	Diff. 1′	Δ = 27°	Diff. 1′	Δ = 28°	Diff. 1′
1	20°15′	+1.01′	21°16′	+1.01′	22°16′	+1.01′	23°17′	+1.01′	24°18′	+1.01′	25°18′	+1.01′	26°19′	+1.01′	27°20′	+1.01′	28°20′	+1.01′
2	21°19′	+1.06′	22°22′	+1.06′	23°26′	+1.06′	24°30′	+1.06′	25°33′	+1.06′	26°37′	+1.06′	27°41′	+1.06′	28°45′	+1.06′	29°48′	+1.06′
3	24°22′	+1.20′	25°34′	+1.20′	26°46′	+1.20′	27°58′	+1.20′	29°10′	+1.20′	30°22′	+1.19′	31°33′	+1.19′	32°44′	+1.19′	33°56′	+1.19′
4	31°41′	+1.60′	33°17′	+1.60′	34°53′	+1.57′	36°27′	+1.55′	41°00′	+1.54′	42°33′	+1.52′	44°04′	+1.51′	45°35′	+1.48′	47°04′	+1.48′
5	100°00′	+0.50′	100°30′	+0.50′	101°00′	+0.50′	101°30′	+0.50′	102°00′	+0.50′	102°30′	+0.50′	103°00′	+0.50′	103°30′	+0.50′	104°00′	+0.50′
6	165°19′	−0.00′	164°48′	−0.00′	164°07′	−0.57′	163°33′	−0.55′	163°00′	−0.54′	162°27′	−0.52′	161°56′	−0.51′	161°25′	−0.48′	160°56′	−0.48′
7	175°38′	−0.20′	175°26′	−0.20′	175°14′	−0.20′	175°03′	−0.20′	174°50′	−0.20′	174°38′	−0.19′	174°27′	−0.19′	174°16′	−0.19′	174°04′	−0.19′
8	178°41′	−0.06′	178°38′	−0.06′	178°34′	−0.06′	178°30′	−0.06′	178°26′	−0.06′	178°23′	−0.06′	178°19′	−0.06′	178°15′	−0.06′	178°12′	−0.06′
9	179°45′	−0.01′	179°44′	−0.01′	179°44′	−0.01′	179°43′	−0.01′	179°42′	−0.01′	179°42′	−0.01′	179°41′	−0.01′	179°40′	−0.01′	179°40′	−0.01′
10	180°00′	0.00′	180°00′	0.00′	180°00′	0.00′	180°00′	0.00′	180°00′	0.00′	180°00′	0.00′	180°00′	0.00′	180°00′	0.00′	180°00′	0.00′

TABLE II.

Externals, Tangents, Radii and Degrees of Curve to a 100 Ft. Circular Arc.

Δ	E	Diff. 10′	T	Diff. 10′	R	D	Defl. per Ft.
1°	0.218	.036	50.001	.001	5730	1°	0.3′
2°	0.436	.036	50.005	.001	2865	2°	0.6′
3°	0.655	.036	50.012	.001	1910	3°	0.9′
4°	0.873	.036	50.020	.002	1432	4°	1.2′
5°	1.092	.036	50.032	.002	1146	5°	1.5′
6°	1.310	.036	50.046	.003	955.0	6°	1.8′
7°	1.530	.036	50.062	.003	818.6	7°	2.1′
8°	1.749	.036	50.081	.004	716.2	8°	2.4′
9°	1.969	.036	50.103	.004	636.6	9°	2.7′
10°	2.189	.036	50.127	.005	573.0	10°	3.0′
11°	2.409	.037	50.155	.005	520.9	11°	3.3′
12°	2.630	.037	50.184	.005	477.5	12°	3.6′
13°	2.851	.037	50.216	.006	440.8	13°	3.9′
14°	3.073	.037	50.251	.006	409.3	14°	4.2′
15°	3.296	.037	50.288	.007	382.0	15°	4.5′
16°	3.519	.037	50.328	.007	358.1	16°	4.8′
17°	3.743	.037	50.370	.008	337.0	17°	5.1′
18°	3.968	.037	50.416	.008	318.3	18°	5.4′
19°	4.193	.038	50.463	.009	301.6	19°	5.7′
20°	4.419	.038	50.514	.009	286.5	20°	6.0′
21°	4.646	.038	50.567	.010	272.9	21°	6.3′
22°	4.875	.038	50.624	.010	260.4	22°	6.6′
23°	5.104	.038	50.683	.010	249.1	23°	6.9′
24°	5.334	.039	50.744	.011	238.8	24°	7.2′
25°	5.565	.039	50.809	.011	229.2	25°	7.5′
26°	5.797	.039	50.876	.012	220.4	26°	7.8′
27°	6.030	.039	50.946	.012	212.2	27°	8.1′
28°	6.264	.039	51.020	.013	204.6	28°	8.4′
29°	6.500	.040	51.096	.013	197.6	29°	8.7′
30°	6.737	.040	51.175	.014	191.0	30°	9.0′
31°	6.976	.040	51.257	.014	184.8	31°	9.3′
32°	7.216	.040	51.342	.015	179.1	32°	9.6′
33°	7.457	.040	51.430	.015	173.6	33°	9.9′
34°	7.700	.041	51.521	.016	168.5	34°	10.2′
35°	7.944	.041	51.615	.016	163.7	35°	10.5′
36°	8.190	.041	51.712	.017	159.2	36°	10.8′
37°	8.438	.042	51.813	.017	154.9	37°	11.1′
38°	8.688	.042	51.917	.018	150.8	38°	11.4′
39°	8.939	.042	52.024	.019	146.9	39°	11.7′
40°	9.193	.043	52.135	.019	143.2	40°	12.0′
41°	9.448	.043	52.249	.020	139.8	41°	12.3′
42°	9.706	.043	52.366	.020	136.4	42°	12.6′
43°	9.965	.044	52.487	.021	133.3	43°	12.9′
44°	10.227	.044	52.611	.021	130.2	44°	13.2′
45°	10.491	.044	52.739	.022	127.3	45°	13.5′
46°	10.757	.045	52.871	.023	124.6	46°	13.8′
47°	11.025	.045	53.006	.023	121.9	47°	14.1′
48°	11.296	.046	53.145	.024	119.4	48°	14.4′
49°	11.570	.046	53.288	.025	117.0	49°	14.7′
50°	11.846	.047	53.435	.025	114.6	50°	15.0′
51°	12.125	.047	53.586	.026	112.3	51°	15.3′
52°	12.407	.047	53.740	.027	110.2	52°	15.6′
53°	12.691	.048	53.899	.027	108.1	53°	15.9′
54°	12.979	.049	54.062	.028	106.1	54°	16.2′
55°	13.270	.050	54.230	.029	104.1	55°	16.5′
56°	13.564	.050	54.402	.029	102.1	56°	16.8′
57°	13.861	.050	54.577	.030	100.5	57°	17.1′
58°	14.161	.051	54.758	.031	98.79	58°	17.4′
59°	14.465	.051	54.943	.032	97.11	59°	17.7′
60°	14.773	.052	55.133	.033	95.49	60°	18.0′
61°	15.084	.053	55.328	.033	93.93	61°	18.3′
62°	15.399	.053	55.527	.034	92.41	62°	18.6′
63°	15.718	.054	55.732	.035	90.95	63°	18.9′
64°	16.041	.055	55.941	.036	89.52	64°	19.2′

TABLE III.

Deg. Curve	Radius	MIDDLE ORDINATES					CHORDS				
		For Chords of					For Arcs of				
		100 Ft.	80 Ft.	60 Ft.	50 Ft.	40 Ft.	100 Ft.	80 Ft.	60 Ft.	50 Ft.	40 Ft.
1°	5730	0.2	0.1	0.1	0.0	0.0	100	80	60	50	40
2°	2865	0.4	0.3	0.2	0.1	0.1	100	80	60	50	40
3°	1910	0.6	0.4	0.2	0.2	0.1	100	80	60	50	40
4°	1432	0.9	0.6	0.3	0.2	0.1	100	80	60	50	40
5°	1146	1.1	0.7	0.4	0.3	0.2	100	80	60	50	40
6°	955.0	1.3	0.8	0.5	0.3	0.2	100	80	60	50	40
7°	818.6	1.5	1.0	0.6	0.4	0.3	99.94	80	60	50	40
8°	716.2	1.8	1.1	0.6	0.4	0.3	99.92	80	60	50	40
9°	636.6	2.0	1.2	0.7	0.5	0.3	99.90	79.95	60	50	40
10°	573.0	2.2	1.4	0.8	0.5	0.3	99.88	79.93	60	50	40
		For Chords of					For Arcs of				
		80Ft.	60Ft.	50Ft.	40Ft.	30Ft.	80 Ft.	60 Ft.	50 Ft.	40 Ft.	30 Ft.
11°	520.9	1.5	0.9	0.6	0.4	2	79.92	60	50	40	30
12°	477.5	1.7	0.9	0.7	0.4	2	79.91	60	50	40	30
13°	440.8	1.8	1.0	0.7	0.4	2	79.89	60	50	40	30
14°	409.3	2.0	1.1	0.8	0.5	3	79.87	59.95	50	40	30
15°	382.0	2.1	1.2	0.8	0.5	3	79.85	59.94	50	40	30
16°	358.1	2.2	1.3	0.9	0.6	3	79.83	59.93	49.95	40	30
17°	337.0	2.4	1.3	0.9	0.6	3	79.81	59.92	49.95	40	30
		For Chords of					For Arcs of				
		60 Ft.	50 Ft.	40 Ft.	30 Ft.	25 Ft.	60 Ft.	50 Ft.	40 Ft.	30 Ft.	25 Ft.
18°	318.3	1.4	1.0	0.6	0.3	0.2	59.91	49.94	40	30	25
19°	301.6	1.5	1.0	0.7	0.4	0.3	59.90	49.94	40	30	25
20°	286.5	1.6	1.1	0.7	0.4	0.3	59.89	49.94	40	30	25
21°	272.9	1.7	1.1	0.7	0.4	0.3	59.88	49.93	40	30	25
22°	260.4	1.7	1.2	0.8	0.4	0.3	59.87	49.93	40	30	25
23°	249.1	1.8	1.3	0.8	0.5	0.3	59.84	49.91	40	30	25
24°	238.8	1.9	1.3	0.8	0.5	0.3	59.84	49.91	40	30	25
25°	229.2	2.0	1.4	0.9	0.5	0.3	59.82	49.90	39.95	30	25
26°	220.4	2.0	1.4	0.9	0.5	0.3	59.81	49.90	39.95	30	25
27°	212.2	2.1	1.5	0.9	0.5	0.4	59.79	49.89	39.94	30	25
28°	204.6	2.2	1.5	1.0	0.5	0.4	59.78	49.88	39.94	30	25
29°	197.6	2.3	1.6	1.0	0.6	0.4	59.77	49.87	39.93	30	25
30°	191.0	2.3	1.6	1.0	0.6	0.4	59.76	49.87	39.93	30	25
31°	184.8	2.4	1.7	1.1	0.6	0.4	59.74	49.85	39.92	30	25
32°	179.1	2.5	1.7	1.1	0.6	0.4	59.73	49.84	39.92	30	25
		For Chords of					For Arcs of				
		50 Ft.	30 Ft.	25 Ft.	20 Ft.	10 Ft.	50 Ft.	30 Ft.	25 Ft.	20 Ft.	10 Ft.
33°	173.6	1.8	0.6	0.4	0.3	0.1	49.83	30	25	20	10
34°	168.5	1.8	0.7	0.5	0.3	0.1	49.82	30	25	20	10
35°	163.7	1.9	0.7	0.5	0.3	0.1	49.81	30	25	20	10
36°	159.2	2.0	0.7	0.5	0.3	0.1	49.80	30	25	20	10
37°	154.9	2.0	0.7	0.5	0.3	0.1	49.79	29.95	25	20	10
38°	150.8	2.1	0.7	0.5	0.3	0.1	49.78	29.95	25	20	10
39°	146.9	2.1	0.8	0.5	0.3	0.1	49.77	29.95	25	20	10
40°	143.2	2.2	0.8	0.5	0.3	0.1	49.75	29.94	25	20	10
41°	139.8	2.2	0.8	0.6	0.4	0.1	49.74	29.94	25	20	10
42°	136.4	2.3	0.8	0.6	0.4	0.1	49.73	29.94	25	20	10
43°	133.3	2.3	0.8	0.6	0.4	0.1	49.71	29.93	25	20	10
44°	130.2	2.4	0.9	0.6	0.4	0.1	49.69	29.93	25	20	10
45°	127.3	2.4	0.9	0.6	0.4	0.1	49.67	29.92	25	20	10
46°	124.6	2.5	0.9	0.6	0.4	0.1	49.65	29.92	25	20	10
47°	121.9	2.6	0.9	0.6	0.4	0.1	49.63	29.92	24.95	20	10
48°	119.4	2.6	0.9	0.6	0.4	0.1	49.62	29.92	24.95	20	10
49°	117.0	2.7	1.0	0.7	0.4	0.1	49.60	29.91	24.95	20	10
50°	114.6	2.7	1.0	0.7	0.4	0.1	49.59	29.91	24.94	20	10

NOTE—Tables I, II and III complete for values of Δ up to 128° in convenient form for use in the field may be obtained from the author at a price of 25 cents per copy.

A REMARKABLE FORM OF SKELETAL ELEMENT IN THE LITHISTID SPONGES

(A Case of Analogical Resemblance)

By H. V. Wilson

With Four Text Figures

Sponges, like other groups, are rich in the structural resemblances which are due to common descent, resemblances which involve numerous organs in the individual animal and which are of such a complex intricate character, striking so deeply into the constitutional make-up, that it is impossible to think of them as due to any natural cause save kinship. But as we study these infinitely variable animals, we encounter resemblances which fall in another category, resemblances which involve only some special detail of structure or at most a few features, which in their actual functioning are correlated in physiological-mechanical function. Such resemblances are certainly, in many cases at least, not inheritances from a common ancestor. We group them together as analogical but they fall in two subdivisions: (1) those involving features which are called out in each individual organism by the stimulus of an environment, and which do not appear when that environment is changed; and (2) those involving features which are racial characteristics, viz., characteristics that have arisen and become fixed, in some way, during the course of evolution and which continue to appear under different sets of environmental conditions.

Analogical resemblances of this latter class are due to the independent occurrence of the same variation (or cumulative series of variations), in different idioplasms. How such germinal changes, mutations as we often call them, are brought about physiologically, is a question that is being actively asked by many students of heredity, especially by the experimental evolutionists, of today. Along with the directly experimental attacks, descriptive work has its use in locating facts which at some time it may be worth while to put under the fire of experiment.

Partly, at least, in pursuance of this idea I wish to record a case of resemblance which is certainly analogical, and which, it is practically certain, is racial. It involves the shape of the fundamental spicule on which the characteristic skeletal element, the desma, of the lithistid sponges is built up.

The desma is a silicious body, in most species of a complexly branched shape (Figs. 3, 4), formed by the continued deposition of silicious material on a silicious spicule which we may call the basic spicule, technically *crepis* (Fig. 1). The basic spicules, which are especially present in growing parts of the sponge, are free bodies, that is, they lie in the living tissues of the sponge unconnected with one another or with other skeletal elements. The desmas on the contrary as they assume the final shape, become articulated with one another, and in most species become firmly united to form a coherent skeleton which presents the appearance of a network of silicious beams.

Now the basic spicule of the desma is in some lithistida a four-rayed spicule (tetraxial or tetractinellid spicule), in others a simple rod-shaped spicule (monaxial). Different as are the basic spicules in these two groups of species, the complete desmas are not always easy to distinguish, for in both cases they may become complexly branched bodies. This superficial similarity of the two kinds of desmas, those built on tetraxial, and those built on monaxial spicules, is in itself significant, but when we find, as we do in some species, desmas of the latter class varying toward desmas of the former class, it becomes clear that the desma built on a four-rayed spicule (tetracrepid desma) is the original or ancestral type, while the desma built on a monaxial spicule (monocrepid desma) is a derived type. These interesting and important variations were first described by O. Schmidt in *Discodermia clavatella* (O. Schmidt, 1879, pp. 12, 24). Sollas (1888, p. 341) confirmed the facts and convinced himself "that a complete series of transitional forms connect the monocrepid and the tetracrepid desmas." Topsent (1904, p. 60) has discovered the same state of affairs in another lithistid sponge, *Macandrewia azorica*.

The four-rayed shape may thus be regarded as the original, actual or ancestral, shape of the spicule which is transformed by the deposition of silicious matter into the desma. This spicule in the case of tetracrepid desmas in general is what is called a *calthrops*, viz., a spicule in which the four rays are similar, making the same angle with one another and having the same length. But in at least one species, *Desmanthus incrustans* Topsent, an evolutionary change has occurred, whereby one of the rays of the basic spicule has become longer than the others, the spicule thus being converted from a *calthrops* into a *triaene*. In the triaene, a very common form of spicule in the non-lithistid tetraxial sponges, we distinguish, then, one

long ray, the shaft (technically *rhabdome*), and three shorter rays (the *cladi,* forming together the *cladome*), which are given off from the end of the shaft. In the sponge which I shall now describe, a further evolutionary change has occurred, and rays are given off at both ends of the shaft of the basic spicule, the spicule thus becoming what is called an *amphitriaene* (Fig. 1).

The sponge referred to is a Philippine form, a new species, *Jereopsis fruticosa* mihi, dredged by the U. S. Fisheries Steamer Albatross in 80 fathoms in the region of the Sulu Archipelago, and which will be described in detail in a forthcoming report on Philippine sponges. It is a stony sponge of branching-cylindrical, or shrubby, habitus, 55 mm. high, and with the free spicules of the genus (dichotriaenes, oxeas, and streptasters including amphiasters and spirasters). In the two other recorded species of the genus, *Jereopsis schmidtii* (Sollas) from the tropical Atlantic and *Jereopsis* (*Neosiphonia*) *superstes* (Sollas) from the tropical Pacific (cf. Sollas 1888, Lendenfeld 1903), the desma is, perhaps, the usual type of tetracrepid desma, built up on a calthrops. Schmidt's figure (1879, Taf. II, Fig. 10) suggests however that this is not the case. I hope at some time to have the opportunity of making a critical examination of the desma, from this point of view, in the type specimens of these two species.

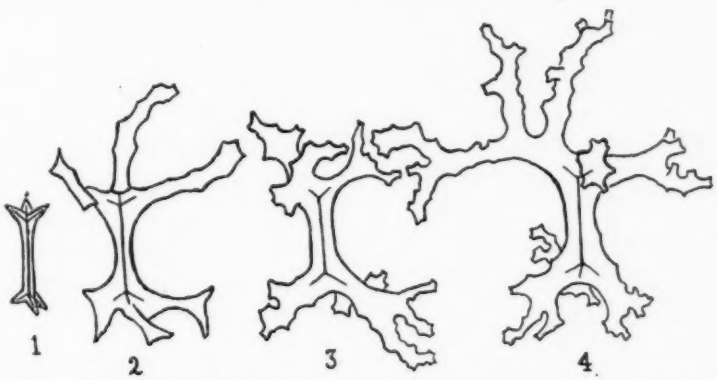
The facts concerning the development and structure of the desma in this sponge (*Jereopsis fruticosa*) are as follows:

Small, perfectly free amphitriaenes (Fig. 1) occur in the superficial (ectosomal) region of the sponge. The spicules are about one-sixth mm. long, and consist of a straight shaft with three rays (cladi) at each end. The streak of peculiar substance, known as the "axial canal," which is found in each of the axes of a tetraxial spicule, here extends, as the figure shows, along the axis of the shaft and to the tip of each ray.

Early stages in the transformation of such spicules into desmas may be found near the surface of the sponge. One is shown in figure 2. Such young desmas are free or only slightly connected with the body of the skeleton. In them the shaft continues to be of about the same length as in the basic spicule (Fig. 1), although it is thicker, but the rays have greatly increased in length. They measure now from one-half to the full length of the shaft or indeed slightly over. They are simple, viz., not branched, and when not corroded their ends bear rounded tubercles for articulation with other desmas. The axial

substance, "axial canal", retains its former size (cf. Figs. 1, 2), thus extending only into the basal part of each ray. This is the characteristic behavior of the axial canal in the growth of the lithistid desma in general.

As such desmas develop their final shape, they become firmly united to the skeletal framework already formed. If one wishes to study accurately their fundamental shape after union, the spicules must be isolated through the application of hydrofluoric acid to rough slices of the framework. When the framework is so treated the desmas fall apart. They are however corroded.



Figs. 1-4. *Jereopsis fruticosa.* Fig. 1, a free and uncorroded amphitriaene from the ectosome. Fig. 2, a young desma, slightly corroded by hydrofluoric acid, from the ectosome. Figs. 3 and 4, adult desmas somewhat corroded by the hydrofluoric acid used to dissociate them from the skeletal framework. All x 150.

Desmas (Figs. 3, 4) obtained in this way show the unchanged axial canal system which indicates the shape of the basic spicule on which the desma has been built up. The shaft is now about three times as thick as in the original spicule but no longer. The rays, better designated now as branches (technically cladi), vary a great deal not only in different spicules but in the same spicule. In some cases they have not advanced over the condition described for the intermediate stage (Fig. 2), either in size or complexity. More often, the branch is itself branched, a condition which is produced, of course, not

by the division of the first branch but by the continued deposition of silicious matter along lines which make angles with the first branch. In this way secondary or even tertiary branches are formed. There is apparently some law of growth which brings it about that no branch shall materially exceed the shaft in length. When or before that point is reached, new branches are formed. The articular tubercles are developed on the ends of the branches, whether the latter be primary, secondary, or tertiary. In many cases, as in Fig. 2, where the branches are about equally developed at the two ends of the shaft, the axial canal system of the basic amphitriaene is conspicuous, but it may be overlooked in cases where, as in Fig. 4, the branches at one end of the shaft are much more extensively developed than at the other end.

The point of importance for this paper is that the basic spicule, on which the adult desma is built, is an amphitriaene, that is a spicule consisting of a shaft and three rays at each end of the shaft. I can find no similar case recorded for the Lithistida.

In the non-lithistid tetraxial sponges, amphitriaenes are recorded only for Samus Gray and Amphitethya Lendenfeld (1906). Samus (one species) is a boring sponge occurring in the South Atlantic, Indian, and South Pacific Oceans. The only megascleres are amphitrianes, which are not all alike. In the larger of these spicules, the shaft, 80μ long, bears at each end three rays, each of which is trifid. In the smaller ones, the shaft, 20μ long, bears at one end three simple rays, and at the other end three trifid rays. While the sponge falls in the Sigmataphora because of its microscleres, which are sigmata (rods curved somewhat in c-shape, but with a spiral twist), its peculiar megascleres give it an isolated position, setting it off as a family (Samidae). The ontogeny of the amphitriaenes is not known, and we have no data on their variation to indicate their origin. It is highly probable however that the spicules have been derived from triaenes, although Sollas (1888, p. 59) has suggested two other conceivable origins.

In Amphitethya (Lendenfeld 1906, p. 126) there is no doubt that the amphitriaenes, which characterize the genus, are derivatives of the triaene. In *Amphitethya microsigma* Lendenfeld, a stalked species with globular body dredged off the west coast of Australia, the facts of variation which demonstrate this are as follows. Triaenes of several kinds occur abundantly in the sponge, those in the more axial

part of the stalk having an especially long shaft, as is often the case in such sponges. In the superficial part of the stalk there are abundant triaenes with short shaft, and mingled with these are the likewise abundant amphitriaenes. The latter spicules, in which the length of the shaft is 160-540μ, are exceedingly variable, scarcely two alike, and they form a close series grading over from amphitriaenes, quite like the spicules I have described above, to the short-shafted triaenes. These observations of the late Professor Lendenfeld securely establish the origin of the amphitriaene. Amphitriaenes were already known in the two other species of the genus, *Amphitethya stipitata* (Carter) and in the sponge from Amboina designated by Topsent *Tetilla merguiensis* Carter (Topsent 1897, p. 437). In the former Sollas noted (1888, p. 49) that "the amphitriaenes sometimes are reduced to simple triaenes." In the latter, the detailed facts, such as similarities in size and precise shape, convinced Topsent that the amphitriaenes are modified triaenes. Amphitethya is a genus with sigmata, and thus falls in the Sigmatophora.

There is still another non-lithistid tetraxonid sponge in which at least a step has been made toward the transformation of the triaene into the amphitriaene. This is *Ancorella paulini* Lendenfeld (Lendenfeld 1906, p. 248) from the Indian Ocean. The spicules referred to consist of a shaft, one millimetre or less in length, which bears at one end three cladi, projecting slightly downward as in an anatriaene, and at the other end a similar single cladus, extending out from the shaft at an angle in the same general direction as the cladi at the opposite end. The sponge is classed in the Astrophora by Lendenfeld, who regards its microscleres (microxeas) as derived from streptasters.

It may be regarded as certain that the presence of the amphitriaene in these several cases is not due to inheritance. The distance of the sponges from one another in the classification, expressing their general dissimilarity, negatives this idea. The comparison of Amphitethya with Jereopsis is especially instructive. Each has plenty of close relatives without amphitriaenes, and the two sponges fall in different suborders of the Tetraxonida. To be sure the Lithistida may not be a natural suborder but a polyphyletic group, some members of which have been derived from non-lithistid tetraxonia with astrose microscleres (Astrophora), and others from non-lithistid tetraxonida with sigmata for microscleres (Sigmatophora). Even in this case

Jereopsis would be related to the Astrophora, Amphitethya to the Sigmatophora.[1]

The only conclusion that is possible is that the triaene has varied and become an amphitriaene, independently, in several groups. The resemblance is analogical, one of 'convergent evolution', a rubric under which we group likenesses that are due to similar responses on the part of related, but not necessarily closely related (witness the similarities between the hydro- and scyphomedusae), organisms to the environment. We classify it, then, as due to a heritable change that may occur in triaenes independently of inheritance, that is, reversion plays no part in its appearance. We would like to know how to evoke it.

If this and similar cases in the sponges should ever be approached experimentally, through the alteration of the external or internal environment, the series of known spicule forms connecting perfect amphitriaenes with perfect triaenes, in *Amphitethya microsigma,* would lead us to expect that the change induced would be more or less cumulative. Also our general knowledge of variation in sponge spicules (cf. Wilson 1904, pp. 9-10) would lead us to expect that the heritable change would probably at first affect comparatively few spicules.

That analogical similarities are common in sponges is generaly recognized, although there is not much that is definite in our knowledge. Nowhere is more emphasis laid on their occurrence than in O. Schmidt's writings. As illustrating Schmidt's standpoint, the following cita-

---

[1] The remarkable character of the lithistid desma makes a strong argument for the monophyletic origin of the group, weakened in no degree by the fact that some desmas are built on four-rayed, others on rod-shaped, basic spicules. For (see above) the variation phenomena in several species show that the latter kind of basic spicule is reducible to the former. Sollas (1888, p. CXIX) has laid weight on this argument for the monophyletic origin of the group, which he derives from the Astrophora. The derivation from the Astrophora in particular is based on the fact that the most frequently-occurring type of microsclere in the Lithistida is astrose. The fairly numerous Lithistida without microscleres offer no difficulty to this theory, for comparative study shows that microscleres have been independently lost during the evolution of various sponges. But the few forms with sigmata (Scleritoderma, Taprobane) do offer a difficulty, if we continue to lay such stress, as now, on differences in the matter of microscleres. The whole question (cf. Dendy 1905, p. 99) can only be raised, but not answered until our critical knowledge is much greater. Alternative hypotheses may be formulated as follows: (1) We may assume a monophyletic origin of the group and trace it back along with the Astrophora and Sigmatophora to Tetraxonida with both kinds of microscleres, asters and sigmata, in which case it would certainly be astonishing that the two kinds of microscleres had mutually repelled one another during the evolution of the Astrophora and Sigmatophora, and again within the Lithistida during the evolution of the existing families. (2) If we assume first the evolution of the Astrophora and Sigmatophora from Tetraxonida with both kinds of microscleres, and then the origin of the Lithistida from the former, it is at least conceivable, as Sollas has noted (*loc. cit.* p. CXX) that the occurrence of sigmata in some Lithistida is a case of reversion. Following out this idea, the reversion to sigmata might conceivably occur in Lithistids that had lost their microscleres. If we assume it to have occurred in forms with microscleres (asters), then again we meet the strange conclusion that sigmata and asters repel one another, the reversional variation which brings back sigmata driving out the asters. (3) If we lay stress in the first degree on the difference in microscleres, we are driven to conclude that the Lithistida have had a double origin, some from the Astrophora, some from the Sigmatophora, and that the habit of forming a complex body, the desma, on a free basic spicule, has been twice acquired. Doubtless the number of hypotheses that are logically sustainable, might be increased.

tions from his "Sponges of the Gulf of Mexico" (1879) may be made. "In the Sponge-fauna of the Atlantic Region, I have shown what a great rôle within the sponges is played by the phenomenon of convergence in the production of pseudo-homologies. These fall under the general concept of adaptations in so far as one is justified in speaking of adaptations to general mechanical laws" (*loc. cit.*, p. 4). Schmidt goes on to say that his entire criticism of characters, in the work of comparing organisms with one another, aims at distinguishing what is the result of inheritance and what the effect of the environment, the latter "only drawn into the stock of hereditary characters in the course of a gradual process of fixation" (an abstract statement into which more than one meaning may be read). He continues and notes that in most contributions of the time, especially those dealing with embryology, the possibility that morphological agreement is not always based on common descent and heredity, is far too lightly passed over (a habit of mind which the progress of physiological-mechanical studies has greatly changed since Schmidt's time).

CHAPEL HILL, N. C.

LITERATURE CITED

DENDY, A. 1905. Report on the sponges collected by Prof. Herdman, at Ceylon, in 1902. In: Herdman Rep. Pearl Oyster Fisheries, Part III, London.

LENDENFELD, R. VON. 1903. Das Tierreich, 19 Lieferung. Tetraxonia. Berlin. 1906. Wissenschaftliche Ergebnisse der deutschen Tiefsee-Expedition, Bd. XI. Die Tetraxonia. Jena.

SCHMIDT, O. 1879. Die Spongien des Meerbusen von Mexico (und des Caraibischen Meeres). Erstes Heft. Jena.

SOLLAS, W. J. 1888. Report on the Tetractinellida collected by H. M. S. Challenger. Edinburgh.

TOPSENT, E. 1897. Spongiaires de la Baie d'Amboine. Revue suisse de zoologie, t. IV.

TOPSENT, E. 1904. Spongiaires des Açores. Résultats des campagnes scientifiques accomplies sur son yacht par Albert 1er Prince Souverain de Monaco. Fasc. XXV. Monaco.

WILSON, H. V. 1904. Reports on an exploration off the west coasts of Mexico, Central and South America, etc. The Sponges, Memoirs Mus. Comp. Zoölogy, Vol. XXX.

THE TURTLES OF NORTH CAROLINA; WITH A KEY TO THE TURTLES OF THE EASTERN UNITED STATES

By C. S. Brimley

The animals known as tortoises, turtles or terrapins, no one of which names by the way has an exact application to any particular group of the order, are distinguished from all other living reptiles by having the body enclosed in a bony shell, leaving only the head, neck and limbs free. This shell consists of two portions, an upper more or less arched portion known as the carapace and a lower, smaller, flattened part known as the plastron. These two are united on each side by a bony bridge or cartilaginous suture.

The majority of existing turtles have the shell covered with horny plates, which do not agree, either in size, number or position with the bony plates beneath (though on the carapace the general arrangement of both is similar), but in two small groups the shell is covered with a leathery skin instead.

The classification of turtles seems somewhat unsettled, but we can distinguish without much trouble a few main groups, whatever may be their exact relation to one another.

1. **Athecae.** Marine turtles with the shell composed of a mosaic of small hexagonal plates which are free from the ribs and vertebrae, and covered with a leathery black skin, and with seven longitudinal ridges down the back. This group includes only the leatherback turtles, the largest of all existing forms.

2. **Thecaphora.** In which the shell is composed of a number of bony plates, agreeing in number with and attached to or composed of the expanded ribs and upper processes of the vertebrae. These are attached to a row of marginal bony plates forming the edge of the shell, and these at the sides to another series of plates forming the plastron.

The Thecaphora comprise the majority of existing turtles and divide into:

(A) The soft-shelled turtles (Trionychoidea) in which the shell is flattened, orbicular and imperfectly ossified around the edges, and covered with a leathery skin. The species occur in most parts of the world.

(B) The side-necked turtles (Pleurodira) in which the shell is covered with horny plates and the neck bends sideways (in a horizontal plane) when drawn back. The species are all south tropical.

(C) The S-necked turtles (Cryptodira) in which the shell is covered with horny plates and the neck bends in a vertical plane when drawn back. The majority of existing turtles belong here, including all the marine species except the leatherbacks.

All of these groups except the Pleurodira are represented in this State or off our coasts, so that at present the turtles are known to be represented in our State by four marine and fourteen inland species.

Of the marine turtles, which, however they may differ in structure, all agree in having the limbs developed as flattened paddles for swimming and in having the front limbs much larger than the hind ones, we get the leatherback, green turtle, loggerhead and bastard turtle.

The leatherback is only occasional on our coast, but one caught near Beaufort is now preserved as a mounted specimen in the State Museum at Raleigh and weighed about 800 pounds. The species is sometimes used as a source of oil.

The green turtle used to be common on our coast but has been hunted so much for food, and its eggs collected for the same reason that it is now very scarce.

The loggerhead and bastard turtle are still quite common in summer and the former breeds but the latter does not, its breeding season being reported to be in the winter on the Florida coast.

These marine species all feed on both marine plants and animals.

Of the land and fresh water forms we get species belonging to three families, while members of a fourth, the Trionychidae or soft-shelled turtles should enter our State from either the south or west or both, but as yet we have no satisfactory records of them.

The three families referred to above are the Chelydridae or snapping turtles with a narrow cross-shaped plastron, large head and long tail; the Kinostermidae, or mud turtles, in which the plastron has ten or eleven plates and is divided into three parts, a fixed middle portion and a front and hind portion, both of the latter, or at least the front part being capable of being moved so as to partially close the shell, and the Testudinidae or terrapins, in which the plastron has twelve plates and is either wholly fixed or divided into only two portions, which are movable on a central hinge.

Only one species of snapping turtle occurs in our State, and this usually goes simply by the name of "turtle," all our other species being known as terrapins in this State. The snapper is the largest and the ugliest of our species reaching a weight of 25 pounds, and is also the one most frequently locally eaten, being in fact quite palatable. It is a voracious and vicious reptile, wholly carnivorous, and capable of inflicting a painful wound if carelessly handled. Its eggs are white, soft-shelled and spherical.

The second family includes two of our species, which much resemble the snapping turtles in habits, but differ in the broad plastron and smaller size, neither reaching a length of more than about four inches in the shell. The mud turtle has the head unstriped, and the plastron nearly as large as the shell opening, while the musk turtle has the head with yellow stripes and the plastron considerably smaller than the shell opening. The latter is more of a deep water animal, the former more of a shallow water form, preferring to hunt for its prey with its shell half in, half out of the water. The eggs are elongated, hard-shelled and white.

The balance of our turtles belong to the Testudinidae and all except one are aquatic and have wholly fixed plastrons.

The exception is the Box Turtle, commonly called Highland Terrapin in this State, which is mainly an inhabitant of damp woods, though I have found specimens buried in the wet mud of a swamp in a place where in a wet season they would have been fifty yards from shore. The short high arched shell and the moveable plastron which closes the shell completely when the animal has withdrawn its head and limbs within, distinguishes this from all our other species. Its food consists of fruit, succulent leaves of plants, and living or dead animals of any kind it can capture.

The remainder of our species differ but little in habits, all being aquatic inhabitants of pools and streams seldom leaving the water except to deposit their eggs, which are elongate and soft-shelled.

Roughly speaking, they divide into two groups, the smaller pond turtles with a smooth shell without variegated markings, and the larger terrapins, collectively often known as river terrapins, yellow-bellies, sliders or cooters, which have the shell almost invariably wrinkled or keeled or both. The former rarely attain a length of over five inches, the latter are from eight inches to a foot or more long when adult.

The small pond terrapins include only three of our species, the speckled terrapin in which the head and shell are marked with round, yellow dots, the mountain terrapin with the yellow markings confined to a yellowish patch on each side of the head just behind the eye, and finally the painted turtle in which the shell has red markings around the edges of the shell. The latter is the larger, attaining a length of five inches when adult, the other two not reaching more than four. The first and last are present in the greater part of our State, the mountain terrapin, in or near the mountain region only.

Of the larger terrapins we get five species of sliders proper, the long-necked chicken turtle and the diamond-back terrapin, the last being a salt marsh species.

The sliders are the largest of the group, some of them attaining a length of over a foot in the shell and a weight of ten pounds. The various species inhabit ponds and large streams and are most plentiful in the Mississippi Valley and the southeastern States.

I cannot say much as to the habits of this group, but of the two species which formerly constituted our Raleigh representatives, one (*Pseudemys concinna*) seemed to be more herbivorous in its habits, and the other (*P. scripta*), more omnivorous, eating flesh as well as plants.

The species are keeled when quite young, and the known young of all species with which I am acquainted are beautifully variegated with yellow and brown or green. Older specimens lose the keel and much of the color pattern disappears, so that many species look totally different when young than when adult.

The chicken turtle enters our list on account of its being recorded from Beaufort in Barbour and Stegneger's Cheek List. Of the habits of the animal in nature I know nothing but it differs in some respects from all our other turtles. The neck is very long, awkwardly long in fact, the shell is high and narrow, but rounded above, not keeled and the color pattern is a large meshed net work of narrow yellow lines on a brown ground. On dissecting out a specimen another marked difference appears, the free portion of the ribs (between the vertebrae and the costal plates) is long, slender and rounded instead of being short, broad and flat as in all our other turtles.

The diamond-back terrapin, the terrapin of the restaurants, is a salt marsh species, found only along the coast and may be recognized by the keeled shells and by the concentric lines on each plate from

which it gets its name. While the article of diet known as terrapin should come from this species, yet as a matter of fact the sliders are also to a large extent shipped to market, though, so far I know, not from this State.

One more group of turtles may be alluded to, namely, the soft-shells, which occur in the Mississippi Valley and the Southeastern States, but have not as yet been recorded from North Carolina.

They have flat, orbicular bodies, a long neck, and a long pig-shaped snout, and though the edges of the lips are fleshy, yet within are sharp-cutting edges which can inflict a painful wound. The species grow to a larger size than any of our inland turtles except the snapper, and are wholly carnivorous in diet.

Little has been said about the recorded distribution of our species and actually but little is known.

Raleigh, as usual, furnishes the best records, with 7 species, Beaufort comes next with 4 marine and 7 inland forms, while no other locality (except Lake Ellis with 6 and Greensboro and Chapel Hill with 4 each) gives us records of more than one or two species.

Yet we may reasonably infer that excepting the mountain terrapin, which is confined to the mountains, and the diamond-back, which is a salt-marsh species of the coast, our prevailing forms must range from the edge of the mountains to the coast, though some of the sliders probably are only found in the eastern half of the State and the status of a few is quite problematical.

A key to practically all eastern turtles follows, by eastern, I mean forms that are found east of the Mississippi, excluding the strictly Mississippi Valley species. The key will probably enable a tolerably intelligent person to identify most of the forms included with reasonable accuracy.

Species already recorded from North Carolina are preceded by a serial number, the rest are in italics and unnumbered, and the name is followedby the name of State nearest to North Carolina in which the species has been taken.

KEY TO THE TURTLES OF THE EASTERN UNITED STATES

1. Limbs long, flat and paddle like: front limbs with not more than two claws each. Marine turtles. See 2.

1. Limbs not paddle like, front limbs with three or more claws on each. Land and Freshwater Turtles. See 6.

2. Shell without horny plates, covered with a black leathery skin, and with seven longitudinal ridges down back. (1) Leatherback Sea Turtle (*Dermochelys coriacea*).

2. Shell with horny plates without longitudinal ridges. See 3.

3. Carapace mottled with yellow, and covered with loosely overlapping plates. Hawksbill Sea Turtle (*Eretmochelys imbricata*). Tropical and subtropical seas.

3. Carapace with smooth, not overlapping, plates. See 4.

4. Claws on front limbs one each, carapace mottled with yellow. (2) Green Sea Turtle (*Chelonia mydas*).

4. Claws on front limbs two each, carapace without yellow mottling. See 5.

5. Plates on under side of bridge three. (3) Loggerhead Sea Turtle (*Caretta caretta*).

5. Plates on under side of bridge four. (4) Bastard Turtle (*Caretta kempi*).

6. Shell covered with horny plates. See 7.

6. Shell covered with a leathery skin, form flattened and orbicular. Soft-shelled Turtles (Family Trionychidae). See 37.

7. Plastron narrow, cross-shaped, the plates of its central portion nine. Snapping Turtles (Family Chelydridae). See 8.

7. Plastron not narrow and cross shaped, its plates more than nine. See 9.

8. Under surface of tail with small scales: carapace with three strong keels at all ages. Alligator Snapper (*Macrohelys temminckii*), Georgia.

8. Under surface of tail with rather large plates, carapace without strong keels in adult. (5) Snapping Turtle (*Chelydra serpentina*).

9. Plastron with ten or eleven plates: front and hind portions of plastron hinged on fixed central portion and capable of partially closing the shell. Mud Turtles (Family Kinosternidae). See 10.

9. Plastron with twelve plates: plastron not as in the mud turtles. (Family Testudinidae). See 15.

10. Plastron comparatively small, hind portion capable of little movement, pectoral plate trapezoidal. Musk Turtles. See 11.

10. Plastron comparatively large, both hind and front parts moveable, pectoral plate subtriangular. Mud Turtles proper. See 12.

11. Head without yellow stripes: shell strongly keeled at all ages. Keeled Musk Turtle (*Kinosternon carinatum*), Georgia.

11. Head with yellow stripes, at least when young, shell not keeled in adult. (6) Musk Turtle (*Kinosternon odoratum*).

12. Carapace with three longitudinal yellow stripes: head with yellow stripes. Baur's Mud Turtle (*Kinosternon bauri*), Florida.

12. Carapace without stripes. See 13.

13. Head with yellow stripes. Louisiana Mud Turtle (*Kinosternon subrubrum hippocrepis*), Georgia.

13. Neither carapace nor head with stripes. See 14.

14. Plastron rather small, bridge very narrow, nasal shield deeply notched behind. Florida Mud Turtle (*Kinosternon steindachneri*), Florida.

14. Plastron and bridge of normal size, nasal shield not notched behind. (7) Common Mud Turtle (*Kinosternon subrubrum* [*pensilvanicum*]).

15. Plastron in two pieces, both movable on a transverse hinge, and joined to the carapace by a cartilaginous suture. See 16.

15. Plastron in one solid piece, joined to the carapace by a bony bridge. See 19.

16. Hind feet fully webbed; shell rather long and narrow, carapace with small yellow dots. Blanding's Turtle (*Emys blandingi*), Ohio.

16. Shell short and high, hind feet little or not at all webbed. Terrestrial species, Box Turtles. See 17.

17. Quadratojugal arch present. Shell usually with narrow radiating lines on each plate. Hind feet somewhat webbed. Gulf Box (*Terrapene major*), Georgia.

17. Quadratojugal arch absent. Carapace with large yellow spots, or broad radiating stripes, or unmarked. See 18.

18. Claws on hind feet three each. Three-Toed Box Turtle (*Terrapene carolina triunguis*), Georgia.

18. Claws on hind feet four each. (8) Common Box Turtle (*Terrapene carolina*).

19. Limbs thick and club-shaped, hind limbs the smallest. Shell with concentric striae on the plates, but not keeled. Terrestrial and burrowing in habits. Gopher Turtle (*Gopherus polyphemus*), South Carolina.

19. Limbs not club-shaped, hind limbs usually the largest. See 20.

20. Masticating surface of jaws narrow. See 21.

20. Masticating surface of jaws broad. See 23.

21. Shell with concentric striae on the plates, giving each plate a lumpy appearance. Shell keeled. Terrestrial. Wood Terrapin (*Clemmys insculptus*), New Jersey.

21. Shell smooth without striae or keel. Shell four inches or less. See 22.

22. Head and carapace with small round yellow spots. (9) Spotted Terrapin (*Clemmys guttatus*).

22. Carapace and head without round yellow spots, a yellow patch on each side of neck.

(10) Mountain Terrapin (*Clemmys nuchalis*),
Muhlenberg's Terrapin (*Clemmys muhlenberg*), N. J.

23. Masticating surface of jaws with longitudinal ridge down middle. See 24.

23. Masticating surface of jaws without longitudinal ridge; shell keeled. See 34.

24. Head and neck when extended about two-thirds length of shell, shell high and narrow, with a reticulated pattern of narrow yellow lines in large mesh. (11) Chicken Turtle (*Deirochelys reticularia*).

24. Head and neck not more than half length of shell. See 25.

25. Size comparatively small, usually not more than five inches in length of shell, shell smooth, no variegated markings on large plates of carapace. Shell with red markings around the edge. See 26.

25. Size comparatively large, adults from five inches to a foot or more in length of shell. Large plates of carapace usually with variegated markings. Plates of shell usually with longitudinal wrinkles. See 27.

26. Costal plates in line with the vertebrals so that the plates are in straight rows across the shell. (12) Painted Turtle (*Chrysemys picta*).

26. Costal plates altering with vertebrals. Western Painted Turtle (*Chrysemys cinerea*), New York.

27. Edge of one or both jaws serrated. See 28.

27. Both jaws with smooth edges. Plastron with more or less black. See 32.

28. Both jaws serrated, with a notch at the symphisis of upper jaw and a strong tooth or cusp on each side of it. See 29.

28. Lower jaw only serrated, no notch or tooth at tip of upper jaw. Plastron wholly yellow. See 30.

29. Carapace red and black, plastron red. (13) Redbellied Terrapin (Pseudemys rubriventris).

29. Carapace as above, plastron yellow and brown. Alabama Terrapin (*Pseudemys alabamensis*), Alabama.

30. Carapace smooth, head very small. Hieroglyphic Terrapin (*Pseudemys hieroglyphica*), Tennessee.

30. Carapace with wrinkles on the costal plates. See 31.

31. Shell comparatively short and high, markings on costal plates mainly transverse. (14) Florida Terrapin (*Pseudemys floridanus*).

31. Shell comparatively long and flat, markings on costal plates confused or reticulated. (15) River Terrapin (*Pseudemys concinna*).

31. Shell with an evident keel at all ages. An upright yellow bar behind eye. Black markings of plastron consisting of a roundish black spot on each of the two front plates (sometimes on all or nearly of the plates). (16) Yellow-bellied Terrapin (*Pseudemys scripta*).

32. Shell usually not keeled except in the very young. Black markings of plastron usually more extensive and elongate. See 33.

33. An oval red spot behind eye, and conspicuous yellow lines on head, neck and limbs. Red-Necked Terrapin (*Pseudemys elegans*), Tennessee.

33. No red spot behind eye, markings on head neck and limbs obscure or lacking. (17) Troost's Terrapin (*Pseudemys troosti*).

34. Shell with concentric striae on the plates. Salt marsh species. See 35.

35. Keel of each vertebral plate knobbed at tip. Southern Diamond-Back Terrapin (*Malaclemmys pileata*), and subspecies, Florida.

35. Keels of the vertebrals not knobbed. (18) Diamond-Back Terrapin (*Malaclemmys centrata*) and subspecies.

36. Keel of shell even, not tuberculate. A triangular yellow spot behind each eye. Map Terrapin (*Graptemys geographicus*), Virginia.

36. Keels of vertebrals rising into knobs or tubercles on each plate, an L-shaped yellow spot behind eye. Lesueur's Terrapin (*Graptemys pseudo-geographicus*), Virginia.

37. Shell with tubercles in front in adult. See 38.

37. Shell without tubercles in front in adult. Brown Soft-Shelled Turtle (*Amyda mutica*), Ohio.

38. Pale lines on top of head united just in front of eyes. Southern Soft-Shelled Turtle (*Amyda ferox*), South Carolina.

38. Pale lines on top of head united near tip of snout. Spiny Soft-Shelled Turtle (*Amyda spinifera*), Ohio.

RALEIGH, N. C.

A LITTLE-KNOWN VETCH DISEASE.

By Frederick A. Wolf.

Plates 2-6

Introduction

In the spring of 1918, a diseased condition of vetch was noted to be quite abundantly present upon the several species growing in the vicinity of West Raleigh, N. C., and in the following season, it was so destructive to hairy vetch, Vicia villosa, that the plants were practically all killed before they had reached the flowering stage. Since hairy vetch is the species most widely grown within the State as a winter cover crop and as a feed crop to be utilized either for grazing or for hay, this disease is to be regarded as of considerable economic importance. All parts of the plant above ground were affected in a manner quite characteristically different from any of the several diseases which had previously come under the writer's observation. It soon became apparent, from microscopic examination, however, that the disease was identical with one which had first been collected in the summer of 1907 on the horticultural grounds of Cornell University, Ithaca, N. Y. Since two concise mycological notes[1] containing brief descriptions of the appearance of the disease and of the structure of the casual organism, comprise the only publications dealing with this malady, investigations were forthwith begun. It is the present purpose, therefore, to report upon these studies, which have been conducted during the past three seasons, as a contribution to our knowledge of the distribution, symptomatology and dissemination of this disease and of the life history and structure of the pathogen.

Distribution

It has thus far not been possible to secure any considerable body of data on the distribution of the disease either within the State or within other States where species of vetch are cultivated. It has been collected in North Carolina, however, within the counties of Forsythe, Rowan, Montgomery, Granville, Wayne, and Wake and has been observed[2] by Mr. Roland McKee, Bureau of Plant Industry, Office of

[1] Atkinson, G. F., and Egerton, C. W. Protocoronospora, a new genus of fungi. Jour. Mycol. 13; p. 185-186, 1907. Preliminary note on a new disease of the cultivated vetch. Sci. N. S. 26; No. 664, p. 385-386, 1907.

[2] From a letter to the writer, dated May 23, 1919.

Forage Crop Investigations, Washington, D. C., to occur in South Carolina, Georgia, Alabama, Mississippi, Louisiana and Tennessee. Even though the disease was first collected in New York as long ago as 1907, plant pathologists generally are not familiar with it and specimens have, for this reason, not found their way into the several large herbaria. Since the disease has not received a common name, and has the appearance of an anthracnose, it is, in this account, designated as false anthracnose.

APPEARANCE OF THE DISEASE

False anthracnose can first be noticed during November and December when the plants are still small. A brownish discoloration which completely girdles the stems of the seedlings is at this time manifest. This discoloration begins near the surface of the soil and extends upward. The main stem becomes dwarfed in consequence and is soon surpassed in size by other shoots which develop below the lesions. In other cases, the main stem is so severely involved that it dies or the entire plant may succumb. The disease may be observed at any time during winter but makes little progress until spring. It then spreads rapidly upward upon the stem, producing characteristic, short, dark-brown to blackish streaks, Fig. 25, which may remain isolated or become so abundant as to quite uniformly discolor all of the invaded portions. Young stem lesions are at first grayish in color and their change through light brown to dark brown or black is due to the pigmentation of the mycelium within the cortical cells. Young stems are killed early in the season whereas older woody ones may live to maturity. The leaves, including stipules, petioles and leaflets, are successively involved, beginning with the lowermost. The lesions, except upon the leaflets, are entirely similar in outline to those upon the stems and pass progressively through the same changes in color. Those upon the leaflets may remain minute and circular with a tendency toward being most numerous along the principal veins or may appear as elongated, dark streaks. Affected leaflets are pale green in color, especially when several hundred spots develop upon a single leaflet, and become markedly chlorotic before the lesions attain their mature depth of color, Fig. 24. They eventually become dry and fall off.

The mature spots on the legumes or pods are so strikingly distinctive that there is no difficulty in distinguishing false anthracnose

of vetch from any other of the diseases of this plant. Young lesions are at first manifest as irregular purplish discolorations. The middle line of these discolored areas becomes whitish following the rupture of the epidermis by the acervulus or fruit-body of the fungus, Fig. 27. The mass of spores which comes out may give to the center of the spot a pale pink or salmon color. With age, the whitish portions of the lesions become black and the purplish halo disappears as the pods become dry. Mature lesions appear as black, elliptical or elongated oblique spots, Fig. 28, their direction being no doubt due to the oblique fibrous structure of the pod.

ETIOLOGY

False anthracnose is caused by an organism, Protocoronospora nigricans, which was described, in 1907, by Atkinson and Edgerton as the type of a new genus. Since, during the writer's studies, this fungus was found to possess certain characters, to be described later in this report, which are common to the true anthracnoses, comparison was made with the several species of Gloeosporium occurring on vetch. Specimens of the two American species, *Gloeosporium Davisii* E. et E. and *G. Everhartii* Sacc. et Syd., which occur on the legumes and on the leaves respectively of *Vicia americana* were loaned through the courtesy of Dr. J. J. Davis, Madison, Wisconsin, by whom they were first collected. The latter species was first described as *G. americanum* E. et E[3]., a combination which had been earlier employed for a fungus occurring on *Arauja albens* (described from Argentina by Spegazzini in Fungi Arg. Pug. II,, p. 36). Even though these two species differ in size of conidia, they will probably be found to be identical when submitted to cultural and inoculation tests. Certainly they are distinct from the organism under consideration.

A form which occurs on stems of *Vicia cracca* in France and was described[4] as *G. viciae* Fautrey et Roum. is also very different and beyond doubt is identical with *Myxosporium viciae* Fautrey. There is furthermore no chance of confusing *Protocoronospora nigricans* with *G. tricolor* Lind which produces a "frog-eye" leafspot disease of *Vicia cracca* in Denmark.[5]

---

[3] Proc. Acad. Nat. Sci. Phila., 1893, p. 167.
[4] Fungi exsiccati precipue Gallici Centurie LV. Revue Mycologique annee 12, 1890, p. 168.
[5] Annales Mycol. 5: p. 277, 1907.

Morphology of *Protocoronospora nigricans*

As was indicated in the preliminary accounts by Atkinson and Edgerton, this fungus presents some very interesting structural features. They call attention, furthermore, to the fact that the gross appearance of the disease, the character of the fruit body, the pale pink or flesh color of the spores in mass, and their appearance when hastily examined under the microscope suggest the genus Gloesporium. Since, however, they found that the spores are borne at the apices of the conidiophores not singly, but in whorls and that these spores on germination bud in yeast-like fashion, characters not possessed by anthracnoses, they believed that the fungus resembled most nearly, the thelephoraceous genus, Corticium, and consequently placed it there in their provisional diagnosis. They did not find opportunity, however, to make a critical study of its morphology.

Methods—In the present investigation, use was made of cultures, of fresh material and of appropriately fixed and stained microtome sections. For the latter purpose, portions of stems, pods, and leaves were fixed in medium strength chromo-acetic acid solution and stained with Flemming's triple stain according to the shortened method recommended by Harper. The most satisfactory preparations showing the cytological features were secured when safranin was allowed to act 1-2 minutes, gentian violet 10-20 minutes and orange G. 20-30 seconds. Many of the details of the manner of penetration of the host and of the development and structure of the acervuli could be satisfactorily studied by microscopic examination of the epidermis stripped from fresh material.

The germination of the conidia and their development into colonies could be followed by repeated examinations of marked conidia planted upon the surface of hardened agar plate cultures. For this purpose, conidia were transferred from a lesion to a drop of sterile water on a microscopic slide. A loopful of this suspension of conidia was transferred to one edge of the agar plate and spread over its surface with a zigzag stroke toward the opposite edge. No effort was made to sterilize the surface of the lesion and in consequence mixed cultures containing bacteria were always secured. The bacteria and conidia were sufficiently well separated toward the ultimate end of the stroke, however, to permit the isolation of single spore cultures or their development and study in situ.

Acervulus—The acervuli are either isolated or variously grouped and are always subepidermal in origin, Fig. 21. They open to the surface by the rupture of the epidermis in the form of a slit through which the conidia escape, or by an irregularly lacerate opening.

The stroma upon which the acervulus is seated usually extends 3 to 4 host cell layers in depth and is made up of compact pseudoparanchyma which is at first colorless and becomes with age brown to blackish, Fig. 13. This stroma completely occupies the interior of the host cells without apparent modification of their cell walls. The nourishing mycelium extends radiately from the periphery of the stroma, Fig. 21, and is confined for the most part to the epidermal and hypodermal cells. It has never been observed to be intercellular and cells whose cavities are practically filled with mycelium contain apparently normal intact nuclei. The hyphae composing this mycelium are also hyaline at first, but darken at maturity. Since the mycelium does not penetrate the xylem tissues there is insufficient interference with the conduction of water to prevent the tips of the plant from growing, even when the stems are involved for the greater part of their length.

The conidiophores arise within the epidermal cells and by their elongation rupture the cuticle which persists for a time as a frayed border at the margin of the acervulus. They are compactly arranged and in section appear palisade-like. They are cylindrical to clavate. in shape and quite variable in size, averaging 20-30 x 6-8μ. Those which are more slender are believed to be the structures which were interpreted by Atkinson and Edgerton as conidiophores intermingled with the basidia.

The conidia are borne in a whorl or crown at the apex of the conidiophore, Fig. 1, 6, 9, 10 and 17. They are not formed on sterigmata, but arise as protrusions from the apical wall of the conidiophore. As they are abstricted, others are formed in their places, resulting in the formation of a mass of conidia which may ooze out of the mouth of the acervulus. The conidia are oblong to subelliptical, straight or curved, continuous, hyaline, granular and measure 12-20 x 3-3.5μ, Fig. 2.

The setae are irregularly disposed through the acervuli, Fig. 13. They are very abundantly present on young vetch stems and can readily be distinguished with a hand lens. They are only sparingly present on old stems, however, and one may not be able to determine

their presence without access to serial sections of material embedded in paraffin. Setae on leaf lesions can best be demonstrated by stripping off the epidermis and making examination with the microscope, Fig. 21. Here acervuli will be found which have as few as a single seta or even none, whereas adjacent acervuli bear as many as six to eight. Setae have not been observed on affected pods, although many serial microtome sections of young and mature lesions have been studied. Since the setae do not stand perpendicular to the leaf surface, it would be difficult to get an entire seta in vertical section and they may, for this reason, have escaped detection. Furthermore, their presence in the genus Colletotrichum is known to be so variable that it is entirely possible that they are never formed in pod lesions. These seta are from two to three times the length of the conidiophores, are brown in color, either one-celled or at most, one-septate and gradually taper to a blunt point.

NUCLEAR PHENOMENA

Since Protocoronospora was provisionally placed in the Thelephoraceae, a family in the order Hymenomycetineae whose members possess basidia which are binucleate in the young condition and which arise from binucleate cells in the subhymenium, it was believed that a study of the nuclear conditions in this parasite would be of prime importance in determining its systematic position. Certain hymenomycetes have, of course, been described the cells of whose carpophores, except the hymenial portions, and the nutritive mycelium were either uninucleate or multinucleate.[6]

Accordingly lesions on stems, which were found to be more favorable for study than those on other parts of the plant, were sectioned and stained with Flemming's triple stain in a manner previously stated. The nuclei were found to vary greatly in size, a condition which has been noted in many other fungi. The largest nuclei measure about 3μ in diameter and are most easily observed in the cells at the periphery of the acervulus, either within the epidermis or within the more deeply lying host tissue. Here the hyphal cells are found to contain one to five nuclei (Figs. 14 and 16). The conidiophores and stromatic cells directly beneath them are found to possess considerably smaller, more numerous nuclei, since as many as twelve is not

[6] An excellent review of this situation with a bibliography of all of the important contributions to the subject is contained in a recent paper by Fitzpatrick, H. M. Crytology of Eocronartium musicola. Am. Jour. Bot. 5: No. 8, pp. 399-419, Pls. 30-33, 1918.

an unusual number (Fig. 17). The conidia were likewise multinucleate but none with more than three nuclei have been observed (Fig. 15). Whether the nuclei in conidia containing more than one nucleus had arisen by mitosis following abstriction of the conidium from the conidiophore or had migrated into the conidium before it had become separated, could not be determined. It is entirely likely, however. that multinucleate conidia arise from both conditions.

GERMINATION OF CONIDIA AND GROWTH IN CULTURE.

The organism causing false anthracnose has been isolated several times in each of the three seasons during which it has been studied. It has been cultivated on plain agar, dextrose agar, and vetch decoction agar, on sterilized vetch stems, steamed vetch seed meal, corn meal and tapioca. On each of these media, the isolated colonies remain small and black and are of the type shown in Figs. 22 and 23. When the cultures are heavily seeded with conidia, a compact black mycelial crust is formed over the surface.

The conidia are extremely variable in their method of germination. The most common method is budding in a yeast-like fashion, Figs. 1 and 4, so that the tertiary sporidia may be observed to be still connected seriatim with the parent conidia. These buds arise terminally or more rarely as lateral projections. The conidia may become once septate early in germination (Figs. 3 and 5) and may develop one or more germ tubes similar to the anthracnoses.

The cells of the parent conidium may become enlarged and brown walled within 48 hours and develop a rudimentary mycelium, Figs. 6 and 11. This mycelium may be so reduced that the original parent cells function both as mycelium and conidiophores, Figs. 6 and 9, in which case new conidia are formed as terminal buds. Quite an extensive, thick, closely septate, brown mycelium forms in other cases which may remain sterile, bud sparingly from lateral conidiophores, Fig. 10, or produce masses of conidia, Fig. 9. All the types of germination and growth illustrated in Figs. 3, 4, 5, 6, 9, 10 and 11 have been observed in the *same* vetch decoction agar plate, made by sowing the conidia on the surface of the agar. Conidia taken directly from acervuli have been found to be budding. In old cultures, abnormal conidia of the types shown in Fig. 7 may occur.

When the conidia are sown on the leaves of hairy vetch, they will within 48 hours, have become once septate, formed a slender tube

leading to a brown ovoid appresorium and penetration will have been accomplished, Figs. 18, 19, and 20. The infection tube arises from the lower side of the appresorium and effects entrance into the epidermis by dissolution of the cell wall. This process was observed several times in 1919 and confirmed during the present season. The mycelium then grows rapidly into adjacent cells and forms a new acervulus at the locus of infection. Within three to four days after infection has occurred, new acervuli have matured and are shedding their conidia, Fig. 21.

LIFE HISTORY OF THE CAUSAL ORGANISM

The false anthracnose fungus possesses only one type of reproductive structure which in the vicinity of Raleigh, N. C., may be produced at any time during the life of its host, or from early in November until the first of July. The organism bearing mature acervuli and conidia has been collected during each month of this eight-month period. It is first evident upon the seedling plants and may cause the outer cortical portions of the stems to be blackened to a height of several inches above the surface of the ground, without, however, invading the xylem portions. The disease makes little progress during winter, however, and only develops rapidly with the advent of favorable conditions which appear usually about the middle of April. It then spreads upward and involves all of the above-ground parts including the pods. Here it usually does not extend more deeply than the skeletal or supportive tissue of the pod wall, Fig. 8, but it may penetrate into the young seed. In case of severe infections such as occurred in 1919, the seed are prevented from developing. Lesions on young seeds show as discolored areas which are not noticeable, however, when the seed have matured. If mature seed taken from directly beneath lesions on the pod wall, are soaked in equal parts of alcohol and glycerin for several months to permit them to soften, and are sectioned, the hyphae or Protocoronospora will be found to have permeated all parts of the seed. Such an infected seed is shown in section in Fig. 12. The palisade-like cells of the young seed represented in Fig. 8-d, have become the Malphigian layer, Fig. 12-a, whose outer cell walls are thickened and show a highly refractive "light line."[1] Beneath is the scleroid layer subjacent to which is the

[1] An illuminating account of the structure of legume seeds to which the reader is referred was prepared by Pammel, L. H. Anatomical characters of the seeds of Leguminoseae, chiefly genera of Gray's Manual. Trans. Acad. Sci. St. Louis. 9; No. 6, pp. 91-273, pls. 7-35. 1899.

vestigal nucellar tissue. The hyphae will be noted to be present in all of these tissues which make up the seed coat and to extend into the storage tissues of the cotyledons beneath, Fig. 12-e.

The initiation of the disease in fields not previously seeded to vetch is due to the planting of infected seed. This is supported by field observations during the past two seasons and by an experiment planned to determine this point. Seed from affected pods were collected by the writer in the spring of 1918, and were sown in a new field. By April 15th of the following spring, the plants were abundantly diseased.

The organism can remain alive during summer on old affected parts which undoubtedly serve as a source of infection where vetch is permitted to reseed itself. No evidence has been secured that the organism possesses any other than the conidal stage although repeated examination has been made throughout the entire year of material kept out of doors in wire baskets. Were an ascigerous stage formed, it is not believed that it could have escaped detection. Furthermore, reproduction by conidia alone has occurred in cultures on the various media previously mentioned. Some of these cultures have been maintained for an entire year without transfer but with the addition of sterile water to replace that lost to evaporation.

Infection Experiments

The organism is such a virulent parasite, as indicated by field observations, that little attention has been given to infection experiments except to study the manner of infection. Three series of inoculations were effected, however, upon plants grown in the greenhouse. Two were made with a crude inoculum consisting of the water in which diseased plants had been washed. This water was atomized upon healthy plants and characteristic lesions developed within ten days. The other was made with pure cultures of the organism grown on agar. A watery suspension of conidia was in this case applied with an atomizer to healthy plants on May 19. The plants were then shaded for 24 hours with a sheet of paper. By May 29 acervuli had matured on the stems and leaves of these inoculated plants.

Host Plants

Protocoronospora nigricans appears to be limited to species of Vicia. It has been observed to be very destructive to *Vicia sativa*

and *V. villosa* although *V. angustifolia* and *V. dasycarpa* are very resistant to attack. This last-named species has been observed, for two seasons, to grow to maturity practically free from disease although it was intertwined with hairy vetch so severely affected that it failed to form pods. The growing of *Vicia dasycarpa*, a species with apparently all of the good characteristics of hairy vetch but which matures a little earlier, instead of *V. villosa*, gives promise, therefore, of being the most satisfactory way of combatting this disease.

General Considerations

Attention was called, as has been stated, by Atkinson and Edgerton in their preliminary report, to two characters possessed by the vetch organism which inclined them to believe that it was related to Corticium. These characters were the simultaneous formation of several spores from a basidium and the germination of these spores by budding. No special significance was attached by these investigators to the observation that the spores were sessile and that new spores were formed in place of those which had fallen away, although the presence of sterigmata and of a definite number of spores are known to be characters commonly present among the Basidiomycetes. Germination by budding appears to be not uncommon however, in both Hemibasidii and Eubasidii. Whatever may be said of these diagnostic characters, they should not be regarded as of as much importance in determining whether or not the organism is an Hymenomycete as the multinucleate character of the mycelium, conidia and conidiophores, a phenomenon not known among the basidium-bearing fungi. Because of this multinucleate condition, the organism is certainly not to be regarded as a member of the great group of fungi, Basidiomycetes.

Several characters, including the gross appearance of the spots, the pale pink color of the spores in mass, the structure and type of development of the acervulus, the presence of setae, the formation of appresoria when conidia germinate on the host, and germination of the type shown in Figs. 3 and 5, suggest its relationship to the form genus Colletotrichum. The conidia in the anthracnoses are borne singly at the end of the conidiophore whereas the vetch organism forms a number simultaneously. Some of the anthracnoses in culture, because of the more or less glutinous nature of the conidia, are known to give the hyphomycetous appearance shown in Figs. 6, 9, and 10. Furthermore, none of the anthracnoses *normally* bud, as

does the vetch fungus. Viala and Pacottet[8] claim to have observed budding in *Gloeosporium nervisequum* on sycamore but an examination of their figures indicates that they must have been working with contaminated cultures. Such a criticism has, in fact, been offered by several investigators, including Shear.[9] These last two characters are sufficiently distinctive to leave no reason for regarding the vetch fungus as an anthracnose.

In the writer's opinion the genus, Protocoronospora, with its single species, nigricans, should properly be transferred to the Melanconiales. It is realized that the various genera in the Fungi Imperfecti are arranged artificially and not phyllogenetically and that it is, therefore, difficult to properly relate the vetch organism. Under this artificial scheme, Protocoronospora should probably be placed near Colletotrichum. Perhaps some other student of this interesting organism will be able to find an ascigerous stage and thus to know its true relationship.

The following brief Latin description is given and involves the changes necessary in the transfer from the Thelephoraceae to the Melanconiaceae.

Protocoronospora Emend.

Acervulis innato-erumpentibus, in stromate pseudoparenchymatico, ex 2-5 stratis cellularum constituto insidientibus, ramuli mycelici ultimi conidiphora efformatibus; setulis atro brunneis; conidia sessiles, hyalina incolora, continua, leves, plures (plurumque 4-8), ex germinatione conidia conformia efformantes.

Protocoronospora Nigricans Atk. et Edg. Emend.

Plagulis angustis in legumibus foliis caulibusque, 2-5 mm. long., 1-2 mm. latis; primum irregulariter purpurascentibus, centro albicantibus v. purpureo cinctis, deinde nigricantibus; stromate subepidermatico e cellularis 6-9μ diam. constituto; setulis paucis v. numerosis, continuis v. uniseptatis atro-brunneis, 60-90 x 5-7μ; conidiophoris ex clavato subcylindraceis, 20-30 x 5-6μ, plurisporis; conidiis sessilibus ex conidiophoris conidia nova continuo gignentibus; conidiis in massa roseolis, ex oblongo ellipsoideis, granulosis, rectis vel curvulis, 12-20 x 3-5.5μ.

[8] Viala, P. and Pacottet, P., Levures et Kystes des Gloeosporium. Ann. Inst. Nat. Agron. V. 5: Fasc. 1. p. 31-73. Figs. 32. Paris, 1906.

[9] Shear, C. L. and Wood, Anna K. Studies of fungous parasites belonging to the genus Glomerella. U. S. D. A. Bur. Plant Ind. Bul. 252, pp. 11-110, Figs. 4, Pls. 1-18, 1913.

Hab. parasitice in *Vicia sativa, V. villosa, V. angustifolia* et *V. dasycarpa.* Amer. bor.

An abundant supply of diseased material has been deposited in the herbaria of the Missouri Botanical Garden and the Office of Mycological Collections, Bureau of Plant Industry.

In conclusion, the writer wishes to express his appreciation and thanks to Dr. C. L. Shear, Bureau of Plant Industry, Washington, D. C., and Dr. E. A. Burt, Missouri Botanical Gardens, St. Louis, Mo., for their opinions and suggestions, given after examination of material, as to the taxonomy of this interesting fungus.

SUMMARY

A vetch disease previously little known has been under investigation during the past three years.

It was first collected at Ithaca, New York, in 1907 and is now known to occur also in North Carolina, South Carolina, Georgia, Alabama, Mississippi, Louisiana and Tennessee.

The disease is caused by *Protocoronospora nigricans* and since its gross appearance suggests an anthracnose, it may be appropriately called false anthracnose.

Dark brown to black, elongated lesions may appear upon any of the above-ground parts of the plant. Pod lesions are especially characteristic since they are oblique to the margin of the pod.

The disease is initiated in new fields by the planting of infected seed. This is demonstrated by the occurrence of hyphae within the seed and by the appearance of the disease on seedling plants in fields not previously seeded to vetch.

The fruit bodies of the parasite are subepidermal in origin and possess setae, and a number of conidia are borne simultaneously at the apices of the conidiophores. As these conidia fall away, new ones form in their places. The conidia germinate in a yeast-like fashion, by septation and the formation of germ tubes, by developing a thickened, short mycelium from which conidia are budded, and by the formation of appresoria from which the infection tubes arise.

It has not been possible to develop an ascigerous stage either in culture or upon affected plant parts kept out of doors.

All parts of the organism are multinucleate and primarily for this reason, it is not believed to be related to Corticium, a thelephoraceous fungus. It is believed to be more nearly like Colletotrichum, one of

the Melanconiceae and is accordingly transferred to this family of imperfect fungi.

Vicia sativa and *V. villosa* become severely affected under conditions in which *V. angustifolia* and *V. dasycarpa* remain practically free from disease.

WEST RALEIGH, N. C.

EXPLANATION OF FIGURES

PLATE 2

Figs 1-7 and 9-11 inclusive, are drawn to the same scale.

FIG. 1. Copy of unpublished camera lucida drawings of *Protocoronospora nigricans*, made by Dr. C. W. Edgerton in 1907. The conidiophores show several stages of conidial formation in whorls at the apex. The formation of yeast-like buds upon germination of conidia is also illustrated.

FIG. 2. Normal conidia of *Protocoronospora nigricans* taken from diseased vetch.

FIG. 3. Germination of conidia in hanging drops of tap water in which vetch stems have been macerated. Septation and the formation of one or more germ tubes is shown.

FIG. 4. The usual type of germination by budding as occurs in tap water, plain agar or various kinds of nutrient agar, 24 to 48 hours old.

FIG. 5. A type of germination not uncommon on a variety of nutrient agar.

FIG. 6. In agar cultures in which certain conidia germinate as in Figs. 4 and 5, others form a thickened, short mycelium which sporulates terminally or from lateral branches.

FIG. 7. Abnormal conidia as appear in old cultures on corn meal.

FIG. 8. Vertical section through a lesion on young vetch pod.

(a) Conidia, conidiophores and fungous stroma;
(b) Hypodermal parenchyma occupied by intracellular mycelium;
(c) Sclerenchyma tissue of pod wall;
(d) Embryonic cells of the younger seed. The palisade-like cells become the Malphigan layer in the mature seed.

FIG. 9. Characteristic short mycelium in agar cultures four days old, showing abundant conidial formation.

FIG. 10. Much branched mycelium with few or no conidia found in the same cultures as the condition represented in Figs. 6 and 9.

FIG. 11. Sterile mycelium from four day old nutrient agar plates.

FIG. 12. Section of mature infected vetch seed, showing the mycelium of Protocoronospora in the various tissues;

(a) Malphigian layer, the outer wall of whose cells is very much thickened and shows the characteristic "light line" so common in seeds of eguminoseae;
(b) Scleroid layer;
(c) Vestigal nucellar tissue;
(d) Epidermis of the cotyledon;
(e) Cotyledonary tissue abundantly filled with starch.

PLATE 2

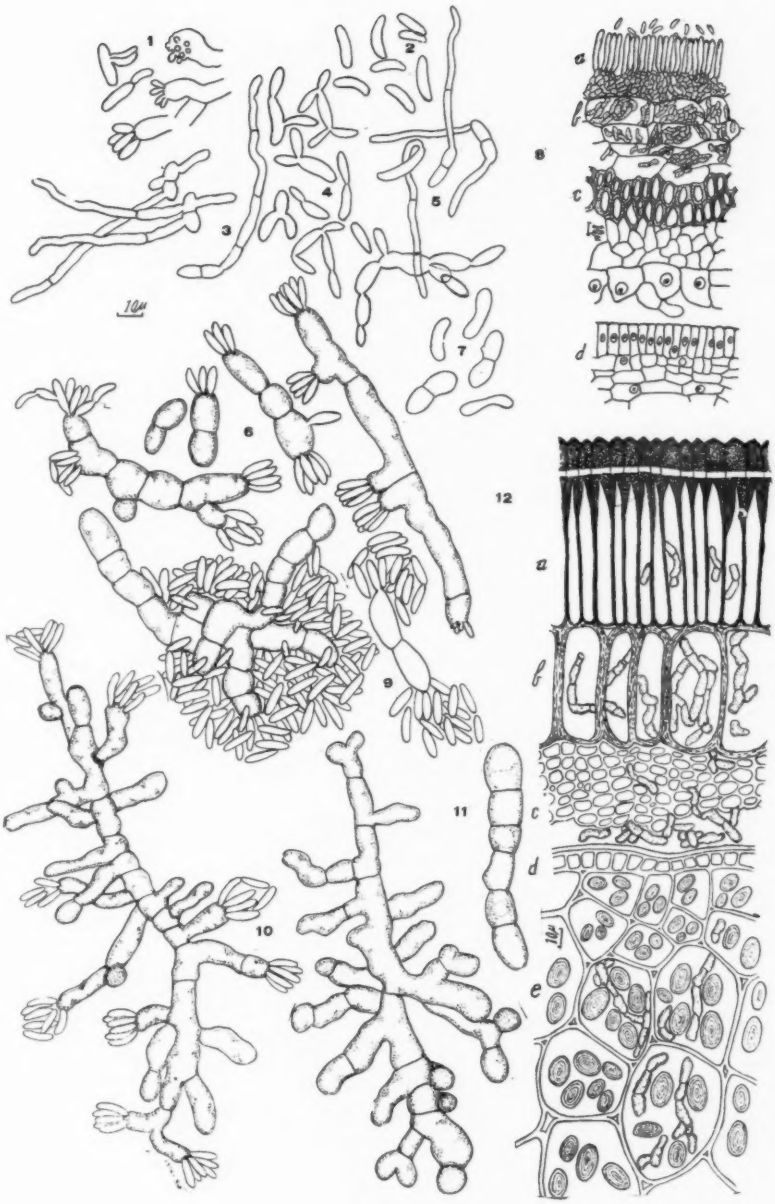


PLATE 3

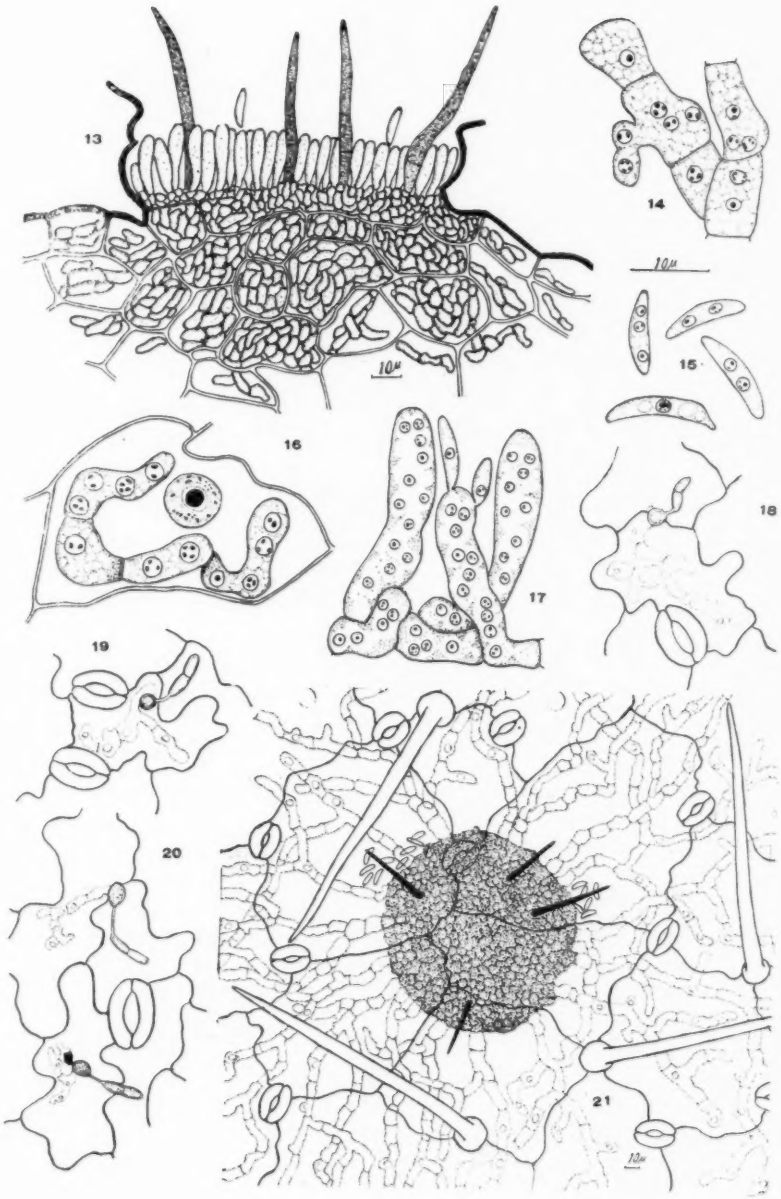


PLATE 4

22

23

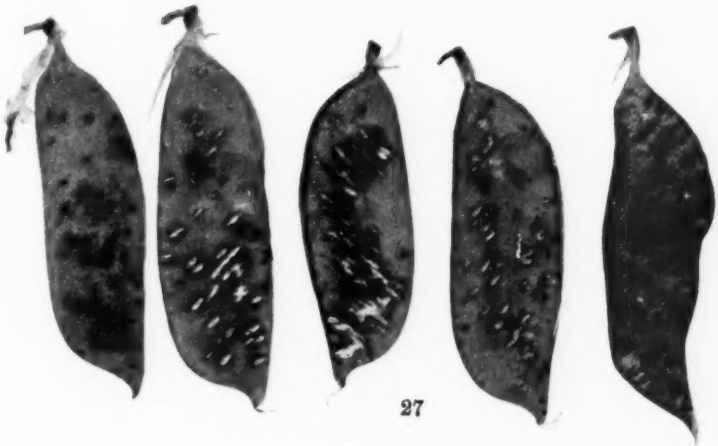
PLATE 5

24

25

PLATE 6

26



27

28

PLATE 3

Figs. 13, 18, 19, and 20, are drawn to the same scale; the magnification of Figs. 14-17, inclusive, is alike.

FIG. 13. Acervulus in cross section of Protocoronospora on vetch stem. The stroma extends 3 to 4 host cell layers in depth.

FIG. 14. Multinucleate mycelium taken from the margin of an acervulus.

FIG. 15. Variation in size and shape of conidia and in the number of nuclei.

FIG. 16. Multinucleate cells from beneath the stroma.

FIG. 17. Multinucleate conidiophores and cells of the stroma.

FIG. 18. Germination of conidium on upper leaf surface of hairy vetch. The formation of the appresorium is followed by infection within 36 to 48 hours.

FIG. 19. Infection through the epidermis on the lower surface of the leaf.

FIG. 20. Penetration by conidia lodged on the upper leaf surface.

FIG. 21. A surface view of an acervulus six days after inoculation.

PLATE 4

FIG. 22. Colonies of *Protocoronospora nigricans*, one week old, on vetch decoction agar.

FIG. 23. Two week's old cultures on the same medium.

PLATE 5

FIG. 24. Lesions on leaves of hairy vetch.

FIG. 25. Stones with elongated, dark brown to black lesions.

PLATE 6

FIG. 26. Pods showing the oblique oblong lesions typical of false anthracnose.

FIG. 27. Young lesions with whitish centers on young pods. The pod at the extreme left of the series had purplish discolored areas but fruit bodies of the causal organism have not yet been formed.

FIG. 28. The dark oblique areas are lesions on mature pods.

NOTES ON THE MOSQUITO FAUNA OF NORTH CAROLINA

By Franklin Sherman

For many years the Division of Entomology, State Department of Agriculture at Raleigh, has been accumulating records of the different species of mosquitoes known in the State, the localities where found, the months when present, etc. Recently this subject has been assumed as one of our regular projects of work. The data included in this paper were not gathered by the author alone,—Mr. R. W. Leiby, of our Division, gave a paper on mosquito control before this body a year ago, and is actively contributing to our records,—so also is Mr. C. S. Brimley. Mr. G. M. Bentley, formerly with the Division, contributed a number of records. Dr. Harvey P. Barrett, of Charlotte, has furnished a large number of records based chiefly on rearings from the larvae, and further work with him is contemplated for this year. Mr. Max Kisluik of the U. S. Bureau of Entomology, stationed at Wilmington, has furnished records from that locality. Many of our determinations have been made by authorities at Washington, notably Dr. H. G. Dyar and the late Messrs. Coquillet and Knab.

The interest in mosquito control was accentuated in the State during the recent war by the work done under the Public Health Service, notably around the camps at Charlotte and Raleigh and shipyards at Wilmington. Since hostilities ceased a number of other communities in the State are undertaking control work in co-operation with the Public Health Service.

The importance of mosquitoes as pests of man need be only briefly mentioned:—it has been abundantly proven that malaria and yellow fever are transmitted by them. There are large areas, even in this State, where land values and crop production are lower than should be on account of malaria. We have had yellow fever cases in past years,—the particular species of mosquito which transmits yellow fever is a fully-established member of our fauna. The irritation, vexation and unrest caused by our many species which merely bite, are known to all.

The main outstanding features of mosquito biology may be sketched as follows: The adult female mosquitoes lay their eggs or or near water. The larvae, called "wrigglers", which hatch from these eggs live in the water, coming to the surface for air. As they are frail

little creatures quiet waters not violently agitated by storms and rapid currents, are most favorable to them. This often means stagnant water, but not necessarily so. Completing its larval life within a week or longer, it changes to a pupa, which stage lasts for a day or longer, when it emerges as an adult, winged mosquito. The length of life of the adult is indefinite,—some live over winter, some species have been kept alive in summer for two months or more. Adult mosquitoes usually fly for distances of less than a mile,—but some species are more migratory, and with favorable light winds may travel much longer distances.

The chief features of mosquito control can be briefly outlined as follows: (1) Drainage of stagnant or standing water when practicable; (2) straightening and clearing of drains to secure prompt disposal of the flow; (3) oiling of such waters as may still serve as breeding places; (4) stocking with small insect-eating fishes of such waters as cannot be guarded by other means; (5) screening of houses; (6) use of smudges, lotions, perfumes, etc. Accepting one mile as the general limit of flight, the Public Health Service extends the drainage work for one mile beyond the limits of the camp, yard, town or other particular area to be guarded.

Most rules have exceptions,—and although mosquitoes adhere quite closely to the general principles just laid down, yet there are certain species which are exceptional in certain particulars and unless we know something about these exceptions, and how to allow for them,—we are liable to unpleasant and disappointing surprises,—and the public, often inclined to snap judgment, may criticise and even abandon control work which is really well done, because of the intervention of exceptional circumstances. Thus the control work in vicinity of Wilmington might be ever so well done,—it might almost, it might entirely eliminate malaria,—yet a favoring breeze might bring into that city countless thousands of mosqutoes of the species *Aedes sollicitans* which breed in the salt marshes of the coast ten to twenty miles away, and which is known to migrate for long distances. Such an invasion, temporary though it may be, might arouse much criticism. A house may be "screened," yet small species of mosquitoes may easily crawl through the meshes of an ordinary fly-screen. A pool may be oiled and yet the mosquito *Mansonia perturbans* may breed from it, because the larva of this species does not come to the surface for air but lives in the saturated mud about the roots of aquatic plants.

There are many variations in exact habits,—certain species are especially prone to enter houses for human victims, others seldom or never do this,—the larvae of certain species predominate in rain-barrels or cisterns, while others are seldom found there,—certain species are active chiefly after sundown, others are equally or more active during the day,—certain species are very averse to flying in a breeze, others take advantage of it to cover long distances. The importance of ascertaining which, if any, of the disease-bearing mosquitoes occur in any locality, is self-evident. This cannot be done by disease-records, for we have no yellow-fever records at present, but we do have the yellow--fever mosquito—so far as we know, it would only require the in-coming of a sufferer from this disease, at the opportune season, to start an epidemic. Hence, it requires the study of the mosquitoes themselves, the study of the mosquito-breeding waters, and the recording of all possible data on each separate species before we can claim to have adequate scientific data bearing upon the mosquito problem as a whole. And this phase of the subject, being the strictly entomological part of it, is the one which claims our chief attention in this

The entire list of species for the State, so far as ascertained, includes 32 species, while it is probable that from 10 to 15 more yet await discovery.

It so happens that we have no positive record of any adult mosquito being taken in February, but we have records for every other month of the year.

The localities whose mosquito fauna is best known are: Charlotte, with a list of 23 species; Wilmington, with 15 species; Raleigh, 13 species; Blowing Rock, 5; Henderson County, 5; Havelock (Craven County), 5. Twenty-three other localities have from 1 to 4 species on record.

Let us now adopt the convenient division of the State into three main regions: eastern, central and western.

1. *Eastern.* This we will consider to include all from the coast to Raleigh and Southern Pines but not including either of those two localities. Twenty-one distinct species of mosquitoes have been taken in this region,—of these, five species have not been taken in either of the other regions, so far as our present records indicate, they are exclusively eastern,—nine of the species have been taken in both the eastern and central regions but not in western,—while the remaining seven species have been taken in all three regions.

2. *Central.* We will consider this region to include Raleigh and Southern Pines and westward to the foot of the Blue Ridge, including Tryon. This reckoning places Raleigh and Charlotte (comparatively well-worked localities) in this area, and gives it a predominance, for the present, in the number of species on record. Twenty-seven species of mosquitos have been taken in this Central region,—eight of which have not yet been taken in the other areas,—nine (as before mentioned) have been taken in central and eastern regions but not in the west,—three have been taken in both central and western areas but not in the east,—the remaining seven have been taken in all three regions.

3. *Western.* We will consider this region to include the strictly mountain area of the Blue Ridge and west of it. Ten species of mosquitoes have been taken in this region, none of which are confined to it,—three of them having been taken in the western and central areas only,—the other seven being ones which have been taken in all three regions.

It is probable that further studies will show some of the species which are now known only in our central area to occur in the eastern area also. Dr. Barrett has taken one or more southerly species at Charlotte, which is further north than they were before known to occur, and such species are very likely to occur in our eastern region whose general fauna appears to be more southerly than at Charlotte. Indeed, the general showing would no doubt be considerably altered in its details, if our knowledge of our mosquito fauna, and its distribution, were as complete as we hope eventually to make it.

Already enough is known to indicate that in number of species the central section of the State will compare with the eastern, whatever disparity there may be in numbers of individuals,—even if all of the species now known in the central region are eventually found in the east, and if no more were found in the central region, its present list of twenty-seven species is sufficient to show that it has a mosquito fauna worthy of consideration. Owing to the presence of larger undrained areas it is undoubtedly true that the total mosquito population is the greatest in the east, and for the opposite reason, least in the mountains. As yet the mosquito fauna of the mountains has been least explored. A complete list from that region would probably show a surprising variety, but the areas for breeding are more restricted.

Adult mosquitoes have been found in our State virtually throughout the year. The number of species which have been taken in each of the several months is as follows: January 2; February none, it so happens; March 3; April 5; May 13; June 14; July 13; August 21; September 9; October 10; November 5; December 3. Of the malarial group two species have been taken at all seasons, these wintering in the adult stage,—the third species of the malarial group has been taken from March to September, inclusive. The yellow-fever mosquito has been taken June to November, inclusive. The species which perhaps breeds more abundantly than any other in eaves-troughs, cisterns and rainbarrels and which is our most common house mosquito, has been taken April to November, inclusive. The exceptional species whose larva lives in mud at the roots of water plants and which, therefore, would not be wholly eliminated by the usual means of control, has been taken in all three regions of the State in the months of June, July and August.

With so many species of mosquitoes in every section (and every other State in this part of the country has a comparable list if worked up and put on record), and with many of them presenting exceptions to the usual rules of mosquito life,—the intelligent and informed citizen will not expect perfect, absolute, complete results from any system of control work. There will be occasions when mosquitoes become abundant, by local breeding or by invasion from outside, in the best-protected areas,—they may even develop in unsuspected places inside the house itself.

It has not been our purpose to here discuss the details of control further than already mentioned,—rather it has been our purpose to give an idea of the mosquito life of the State as a whole, so far as now known.

NOTES ON THE SPECIES

Arrangement is alphabetical. Many of the notes are from Smith "Report of Mosquitoes of New Jersey," or Howard, Dyar and Knab "Mosquitoes of North and Central America."

1. *Aedes atlanticus,* Dyar and Knab. An inhabitant of swamps and woods. Not known to invade houses. Taken in east part of State,—May, June and August.

2. *Aedes atropalpus,* (Coq.) D. and K. A small species, rather northern. Taken in central and west parts of State,—no record as to month.

3. *Aedes bimaculatus,* (Coq.) D. and K. A southerly species. Life and habits not fully known. Larvae taken at Charlotte in July.

4. *Aedes calopus,* (Meigen) D. and K. This is the species which transmits yellow fever. Flies and bites in day. Invades houses. Taken in east and central parts of State,—June, July, August, September, October and November.

5. *Aedes canadensis,* (Theobald) D. and K. Larvae in woodland pools. Adults seldom leave woods. Of wide range, but as yet taken only in east and central parts of State,—April, May, June, July and August.

6. *Aedes mitchellae,* (Dyar) D. and K. A southeastern species. Taken at Wilmington in December.

7. *Aedes sollicitans,* (Walker) D. and K. A coastwise species, the larvae living chiefly in salt marshes, but also in brackish or fresh water. Known to fly as much as 40 miles inland. Taken at Wilmington and Beaufort on our coast, and recorded at Charlotte where perhaps carried by train,—June and August.

8. *Aedes sylvestris,* (Theobald) D. and K. One of the species which frequents porches and sometimes enters houses. A common species of wide range. Taken in east and central parts of the State,—May, June, July and August.

9. *Aedes taeniorhynchus,* (Wied) Busck. A coast-wise species of rather small size which migrates, but not so far as *sollicitans.* Bites in daytime. Does not seem to enter houses, but has been taken on porches. Taken at Wilmington and Beaufort on our coast,—May, June and August.

10. *Aedes tormentor,* D. and K. A southern species taken as far north as Arkansas and recorded for Charlotte in our State,—without record as to month.

11. *Aedes triseriatus,* (Say) D. and K. A species whose larvae live chiefly in water caught in holes in trees,—the adult being a ready biter in the woods, but not entering houses. Taken in all three regions (east, central and west) in our State,—May, June, August, September and October.

12. *Anopheles crucians,* Wied. This is one of the malarial group and known to be a carrier of the "aestivo-autumnal" form of malaria, but not of other forms. It bites late in day and early morning as well as at night, and readily enters houses. Taken in east, central and west parts of our State,—March, May, June, August and September. As with others of this group the body is usually tilted at an angle while biting. Wings spotted.

13. *Anopheles quadrimaculatus,* Say. This species is believed to be the most frequent carrier of malaria. Winters as adult. Taken in east and central parts of the State, not yet in the west,—January, April, July, August, September, October, November and December. Body tilted when biting. Wings spotted.

14. *Anopheles punctipennis,* Say. Has been apparently proven to transmit malaria, but not believed to do so as freely as the preceeding. Winters as adult. In our State this seems to be the most common of the three species of the malarial group. Taken in east, central and west parts of State in every month with one exception (Feb.) Body tilted when biting. Wings spotted.

15. *Coelodiazesis barberi,* (Coquillet) D. and K. Breeds in water in holes in trees, and sometimes present in woods when country is so dry than few other kinds are present. A small species. Our only State record is from Tryon at foot of mountains, without mention of the month.

16. *Culex floridanus*, D. and K. A very small southern species, recorded from Charlotte for July and August.

17. *Culex melanurus*, Coquillett. A dark-colored species of wide range which apparently does not bite. Our only record is from White Lake (Bladen County) in May.

18. *Culex peccator*, D. and K. A rather small southern species, recorded from Arkansas, and from Charlotte in our State in August. Apparently a frequenter of caves and tree-holes. Not known whether it bites.

19. *Culex quinquefasciatus*, Say. This is probably our most abundant and universally-present house-frequenting mosquito. Larvae abundant in rainbarrels, cisterns, troughs, temporary pools, sluggish and foul water, etc. Corresponds to the common *C. pipiens* of the northern States. Taken in east, central and west parts of the State,—April, May, June, July, August, September, October and November.

20. *Culex restuans*, Theobald. In general character like the preceeding, but not so abundant, nor breeding in so foul water. Our records are from the central and west parts of the State,—June and October.

21. *Culex salinarius*, Coquillett. A species of wide range, though also occurring close to coast, hence the name. Enters houses. Taken in east and central parts of the State,—May, August, September, October and November.

22. *Culex territans*, Walker. A rather small, dark species which perhaps does not bite persons. Our only records are for Charlotte and Blowing Rock, —August.

23. *Culiseta inornatus*, (Will.) Dyar. A rather large species which freely bites cattle and horses, perhaps in preference to man. Of wide range but our few records are from Wilmington and Charlotte,—March.

24. *Mansonia perturbans*, (Walk.) Dyar. The larva lives in mud at roots of aquatic plants, not coming to surface for air. A species of wide range. Enters houses. A fierce biter. Taken in east, central and west parts of the State,—June, July and August.

25. *Megarhinus septentrionalis*, Dyar and Knab. A very large mosquito with metallic blue lustre, often found on flowers. Taken east, central and west in the State,—July, August, September and October.

26. *Orthopodomyia signifier*, Coquillet. A wide-spread species not positively known to bite. Our only records are from Raleigh and Charlotte,—October.

27. *Psorophora ciliata*, (Fab.) Rob.—Des. A large species with erect scales on the legs giving fringed appearance. Ready biter and goes indoors, but not usually abundant in houses. Taken in eastern and central parts of State,—May, June, August, October.

28. *Psorophora columbae*, Dyar and Knab. A day as well as evening biter. Seldom indoors. East and central parts of State,—May, July, August.

29. *Psorophora discolor*, Coquillett. Our only record is from Charlotte,—July and August.

30. *Psorophora howardi*, Coquillet. A large species, of which our only record is Charlotte,—without indication of month.

31. *Psorophora sayi*, Dyar and Knab. A species of wide range, a severe day biter, but apparently not usual in houses. Our records are from east, central and west parts of the State,—May, June, July, August and September.

32. *Wyeomyia smithii*, (Coq.) Felt. The larva of this species is known to live normally in the water contained in the stems of pitcher-plants. The adult is not known to bite. Our only record is from Boardman (Columbus County)—larvae in pitcher-plant in April.

RALEIGH, N. C.

AN INTERESTING FERTILIZER PROBLEM

By H. B. Arbuckle

Last summer a large number of farmers in Rockingham county suffered almost total loss of their tobacco crop. It so happened that one of these farmers used two bags of fertilizer that he had kept over from the previous year. He observed that the rows of tobacco upon which he used this old fertilizer to the very plant in the row where he changed to the new fertilizer grew off well and produced well. All the rest of his tobacco was stunted and never showed any growth except in very rainy weather.

This was sufficient to fix suspicion upon the new fertilizer. This led to my investigation. The fertilizer was marked "For Tobacco" and the tag showed a guaranteed analysis, 8-2-2. On analysis the fertilizer checked up very well as 8-2-2. The nitrogen was a little low as determined by Kjeldahl, showing approximately 1.5. It is interesting to note that when the nitrogen was determined by Dumas, it ran distinctly higher.

The fertilizer was at once tried out on boxes of clover and rye at the rate of 1,000 lbs. per acre and compared with a fertilizer prepared in the laboratory to yield 8-2-2, the potash being supplied as potassium sulphate and the nitrogen as sodium nitrate. In these experiments the fertilizer under investigation showed up to fine advantage, showing distinct advantage over the prepared fertilizer. Having no tobacco plants at this time, the fertilizer was reported as good, but the farmers insisted that it be tried out on tobacco. After growing a lot of tobacco plants a set of boxes was prepared to test this fertilizer in varying amounts and other fertilizers prepared with potash and nitrogen from different sources. Having discovered that the fertilizer under test contained over 1% of chlorides and knowing that chlorides were not good for tobacco, the chlorine was removed from the fertilizer. It was found that the tobacco plants in the boxes in which 600 lbs. was used in the row or 1,000 lbs. mixed with the soil were nearly all killed. The few plants remaining were pale and sickly and produced no growth in two months time. The plants in those boxes fertilized with 1,000 lbs. of the fertilizer with the chlorine removed grew nicely, comparing favorably with the best fertilizers prepared for tobacco.

Knowing that one per cent of chlorine could not kill tobacco, boxes were prepared in which we used as much as 200 lbs. of sodium chloride per acre. As was expected this did not injure the plants. The chlorides do not affect the growth, but only the burning quality of the tobacco.

We next tried the fertilizer on tomato plants and found that these were injured, but not as much as the tobacco plants. Then we investigated various solutions of the fertilizer. We found it was the water solution alone that injured the tobacco. A small plant in a beaker was killed in twenty-four hours by the application of a solution that represented 2,000 lbs. per acre. Next we removed the organic matter by prolonged heating, taking up the ash with hydrochloric, sulphuric and nitric acids. The plants were injured not at all by the water solution of these salts, but little growth was shown, because the organic matter unquestionably stimulates plant growth, as could be shown in the study of stable manures. It was noted with interest that the nitric acid solution gave after a time a most vigorous growth. This might have been expected. We then tried water solution of the fertilizer under investigation after heating for an hour at 120° for thirty minutes. We found that this solution when applied in quantities representing 1,000 lbs. per acre gave excellent results.

The toxic substance or substances present seemed to be removed or changed by heat. We repeatedly demonstrated the good results with the fertilizer thus treated. We now had the explanation of the puzzling fact about the chlorine. In removing the chlorides with silver sulphate, heat was employed to avoid the loss of the phosphates. The heat had destroyed the toxic substances in this case as in the case of the straight samples.

By accident we discovered that the toxic substances are also removed by leaving the fertilizer exposed to the sunlight in a warm place, as a bottle containing the fertilizer was left for one week in the balance room where it was exposed to strong light from the south. Water solution of this exposed fertilizer had no effect whatsoever on tobacco plants.

Thus it appears that there is an organic substance present in this fertilizer, which is toxic to tobacco plants and tomato plants, while it has no effect upon rye and clover. This toxic substance is made harmless by heating or by exposure to sunlight. What the substance is still remains a puzzle. Thinking it might be a nitrogen compound, prob-

ably an amido compound derived from decomposition of tankage or some form of animal nitrogen, we determined the nitrgen in samples of the fertilizer after it had been rendered harmless. The percentage was higher than in the original sample. This, however, may be due fact that the water content had been changed. Unfortunately, we had not determined this in the original samples. We carried through a set of experiments to see how many organic substances containing nitrogen were toxic to tobacco plants.

These experiments showed several substances that were quite toxic, notably the nitro phenols, pyridine and piperidine. This was but a confirmation of experiments conducted by Cameron. Here is an interesting problem that deserves the attention of the fertilizer manufacturer, especially in this day, when he is ransacking the world to find sources of potash and nitrogen. In the future will it not leave the manufacturer liable if he sells a fertilizer with a guarantee that it will grow a particular crop and it is found to injure it?

In this particular case the tobacco fertilizer did enormous damage.

It can be rendered harmless in a very simple way, but it is the manufacturer's job to discover this and not the farmer's. This should lead to the testing out of samples of every fertilizer sold for a particular crop.

DAVIDSON, N. C.

AZALEA ATLANTICA ASHE AND ITS VARIETY LUTEO-ALBA N. VAR.

By W. C. Coker

Plates 1 and 7

For about eight years I have had under observation a striking species of Azalea, a typical and abundant constituent of low, damp, pine barrens of the coastal plain. My brother, James L. Coker, Jr., first called my attention to the distinction between this species and *A. nudiflora*, which blooms at the same time and with which it is often confused by careless observers. The species is not included in the treatment of the genus in the North American Flora by Dr. Small, but in April, 1917, Mr. W. W. Ashe published in the Bulletin of the Charleston Museum (13: 26. 1917) a new species, *Azalea atlantica*, the description of which agrees well with our plants except that the color was said to be rose-purple or reddish. As our plant has essentially white flowers throughout its range it seemed improbable that they could be the same. However, on talking with Mr. Ashe he admitted that the flowers were nearly pure white when open, thus removing the principal point of difference. I have also now at hand a specimen in flower from the type locality (Georgetown, S. C.) sent me by Mr. T. G. Harbison on April 26, 1918, and find it the same as Hartsville specimens in all essentials. I now have the plant (from Hartsville) in cultivation in the Arboretum of the University of North Carolina, where it flowered this year.

Azalea atlantica Ashe.

The typical form of the species, as I have observed it, may be described as follows:

Shoots low, slender, strict, hairy or glandular when young, smooth later, sparingly branched, about 15-55 cm. (6-18 in.) high, springing from underground runners and thus forming extensive colonies; leaves up to about 4 cm. long and 1.7 cm. broad, elliptic to obovate, the base pointed at the very short petiole, the tip with a short mucro, margin not recurved or slightly so, ciliate with curved tooth-like hairs, upper surface smooth or sparingly pubescent, the lower nearly smooth or moderately pubescent, grayish-green, the midrib not ciliate (or ciliate, at least when young, in the Georgetown plants). Flowers appearing during the whole of April, 3-4.5 cm. long, glandular and sparingly pubescent or only glandular, not hairy, very fragrant, unfolding before the leaves or in part lagging and simultaneous; corolla tube 2-3 cm. long, expanding

into the open throat, the acute petals with a spread of 3-4 cm., color pure white when open except for a blush of pink or purple on outside near base of tube; the buds more pink. Calyx two-thirds to three-fourths as long as the ovary, varying (in the North Carolina plant) to nearly as long, the strap-shaped lobes blunt, unequal, and upright (recurved or revolute on drying at times), separate to near or below the middle, glandular only or both glandular and with the margin hairy; ovary about 4 mm. long and 3 mm. thick, style about 4-6 cm. long, pale pink to greenish white, hairy (not glandular) over lower half or two-thirds, the knob-like stigma greenish brown; stamens well exserted (about 2 cm.), but not nearly so much so as in *A. nudiflora*, whitish or pale green; pedicels about 7-13 mm. long, pink or greenish. Mature pods about 2 cm. long and 6-7 mm. thick, pointed, somewhat curved, nearly glabrous, dark. Floral glands reddish, very short-stalked, present on pedicels, calyx, ovary and on the outside of the corolla tube and along the central keels of the spreading lobes. Odor strong and very pleasant.

Azalea atlantica var. **luteo-alba** n. var.

Flowers smaller, white when open, the buds and opening flowers with a decided yellowish tint; not pinkish. Otherwise as in the type. Occurring in similar habitats as the type but in separate colonies, and not intermixed. We have found it only at Hartsville, S. C.

A well-marked species that is easily distinguished from *A. nudiflora*, which occurs plentifully in the same territory, though rarely intermixed. It differs in the white, very fragrant, and viscid-glandular (not hairy) flowers with longer tubes, more open throats, much larger calyx, shorter and stouter ovary, and less exserted stamens; by the dwarf size and extensive underground runners; and by the absence of cilia on the midrib. The habitat is also not the same, *A. atlantica* being found in low, damp, undrained pine flats of the coastal plain, while *A. nudiflora* prefers the better-drained soil by ditches, branches or bluffs and extends far beyond the range of the former. *Azalea viscosa*, which is really nearest, is, of course easily distinguished by large size, late flowering (late May to July), and different habitat and habit. It is the only other Azalea of the region occupied by *A. atlantica* and *A. nudiflora*, with the possible exception of the next. *Azalea canescens*, which has the leaves whitish-pubescent below, occurs on better-drained soil, is rose-flowered, is not viscid, and has the same size and habit as *A. nudiflora*, which is very near. Compared with specimens of *A. canescens* at the New York Botanical Garden our plants were easily seen to be different. One plant from Orangeburg, S. C., in the New York Botanical Garden Herbarium, labelled *A.*

PLATE 7

AZALEA ATLANTICA

canescens but different from the others, may be our species. *Azalea glauca,* which seems a small form of *A. viscosa* occurs from New England to Virginia and blooms from June to July.

Azalea atlantica is one of the most conspicuous flowers of the damp, flat woods of the low country, often covering acres under old field or long-leaf pine, and scenting the air for a long distance with a fragrance that is far more pleasant than the much less obvious odor of *A. nudiflora.* We have the plant from Georgetown, S. C., Hartsville, S. C., and Brunswick County, N. C., and have seen it in New Hanover County, N. C. It is probably distributed over most of the coastal plain of North Carolina and South Carolina. The plants from Brunswick County are a slightly different form from the South Carolina plants. The calyx is not hairy, the leaves are smooth on both sides, and the flowers are glandular only. In the Georgetown and Hartsville plants the calyx lobes are a little shorter and less fused, and are quite hairy on the margin in addition to being glandular; furthermore, the flowers are slightly tomentose as well as glandular.

Plate I was painted by my niece, Dorothy Coker, from Hartsville plants on April 25, 1915. It is 4/7 natural size. The photograph (Plate 7) was made by me in Brunswick County, N. C., about half way between Wilmington and Southport on April 6, 1918.

CHAPEL HILL, N. C.

A NEW SPECIES OF ACHLYA

By W. C. Coker and J. N. Couch

Achlya Orion n. sp.

Hyphal threads long, reaching a length of 1.5 cms. on house-flies, more slender than in most Achlyas, from 10-40μ thick close to base, rarely up to 85μ thick, often wavy; usually little branched and pointed at tips when young; becoming considerably branched with age. Sporangia abundant, cylindrical, usually borne singly on the tips of the main hyphae in young cultures, renewed by cymose branching, often forming several clusters at regular intervals on the same hypha, irregular and wavy in old cultures, 12-37 x 36-600μ (rarely up to 900μ). Spores 9-10μ thick, emerging as usual in Achlya, but often falling to the bottom in an open group instead of forming a sphere at the sporangium mouth. Oogonia abundant on flies, grubs and vegetable media, spread over the entire culture from bases of hyphae to tips, giving the culture a lacy interwoven or net-work appearance; the diameter 30-60μ, commonly 32-48μ; usually borne singly on long, crooked, recurved stalks which arise racemosely from main hyphae and which vary in length from 2-10 times the diameter of the oogonia; often oogonial stalks may branch bearing two oogonia and rarely oogonia may be borne on a stalk which arises directly from another oogonial wall; very rarely intercalary; oogonial wall usually without pits (except where the antheridial tubes enter) when grown on flies or grubs, but as a rule with pits when grown on boiled corn. Eggs 1-8, usually 1 or 2 in each oogonium; 25-45μ in diameter, most 33-36μ, eccentric when ripe with one large oil drop; usually spherical, but often elliptical from pressure. Antheridial branches almost always androgynous, usually arising from the oogonial stalk itself, less often from the main hyphae; rarely diclinous; antheridia on about 75% of the oogonia, one or two on an oogonium, tuberous; antheridial tubes obvious penetrating the oogonia and reaching the eggs.

The species seems to be quite rare, having been recognized only twice in considerably over a thousand collections, made by the senior author and his students. It was found in some water and trash collected from the west branch above the Meeting of the Waters

(No. 6 of September 26, 1919), and in the same kind of material from the branch in Battle's Park behind Dr. Pratt's residence (No. 4, June 10, 1920). The description has been made from cultures descended from a single spore.

Our plant can be distinguished (with the unaided eye) from most other Chapel Hill Achlyas by the network appearance given it by the oogonia being scattered over the entire culture from the bases of the hyphae to the tips. *Achlya racemosa* approaches this network appearance more than any other species of Achlya but in the latter the oogonia are not nearly so abundant nor do they extend entirely to the tips of the hyphae. In some species, such as *Achlya oblongata*, the oogonia are borne in a definite zone near the substratum and from half to two-thirds of the length of the hyphae from the tips backwards are without oogonia. In the *Prolifera* group the oogonia are scattered more or less over the entire culture but the big hyphae and long sporangia dissipate the net work appearance.

If we ignore the egg structure, the present species seems to be closest to *Achlya polyandra* Hildb. The two plants resemble each other in the long, racemose oogonial branches which are recurved at the tip; in the often branched antheridial stalks which arise chiefly from the oogonial branches; and in the smooth oogonial walls which are normally without pits except where the antheridia touch. The two species are readily distinguished, however, by the difference in the number of eggs in the oogonia, and in the size and structure of the eggs. In *Achlya polyandra* the number of eggs varies from five to twenty-five, the usual number being ten to fifteen, their average diameter is 27μ and they are said to be centric; in *A. orion* the usual number of eggs is one to two, the diameter of most 33-36μ, with an eccentric structure. In *Achlya polyandra* the sporangia are reported as often not abundant, and secondary ones rare; while in our plant both primary and secondary sporangia are abundant. This species is named for the nebula in Orion, which a photograph of the magnified culture somewhat resembles. This photograph, together with drawings by J. N. Couch will appear in a volume by W. C. Coker on the *Saprolegniaceae of the United States* to be published soon.